New Scientist

HAVE WE JUST DESTROYED THE MULTIVERSE?

WHAT SCIENCE REALLY SAYS ABOUT TEENS AND PHONES

WHY AN ANCIENT FISH IS TO BLAME FOR YOUR SENSITIVE TEETH

WEEKLY 31 May 2025

SPECIAL ISSUE

THE POWER OF IMAGINATION

Why imagination evolved / **The four types of imagination** / Can AI imagine? / **The art of thinking yourself healthier** / The true science of manifesting / How imagination changes as you age / **Take the imagination test** / *and more*

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How to insure a hobbit, and other questions from the frontiers of fantasy mathematics

Join Tom Crawford on a tour through the real-world maths of the most absurd fantasy universes on 19 October at London's Excel Centre. Drawing on a decade's research at some of the world's leading universities, he answers all the most bamboozling maths questions raised by *The Lord of the Rings*, *Star Wars* and more.

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Tour

A journey through science and history: Modern medicine in Paris, France

Embark on an exploration of Paris, where groundbreaking advancements in science shaped the modern world. Discover the evolution of medical practices and scientific thought in a city that became a hub for intellectual innovation. This five-day tour starts on 20 July and costs £2557.

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Podcast

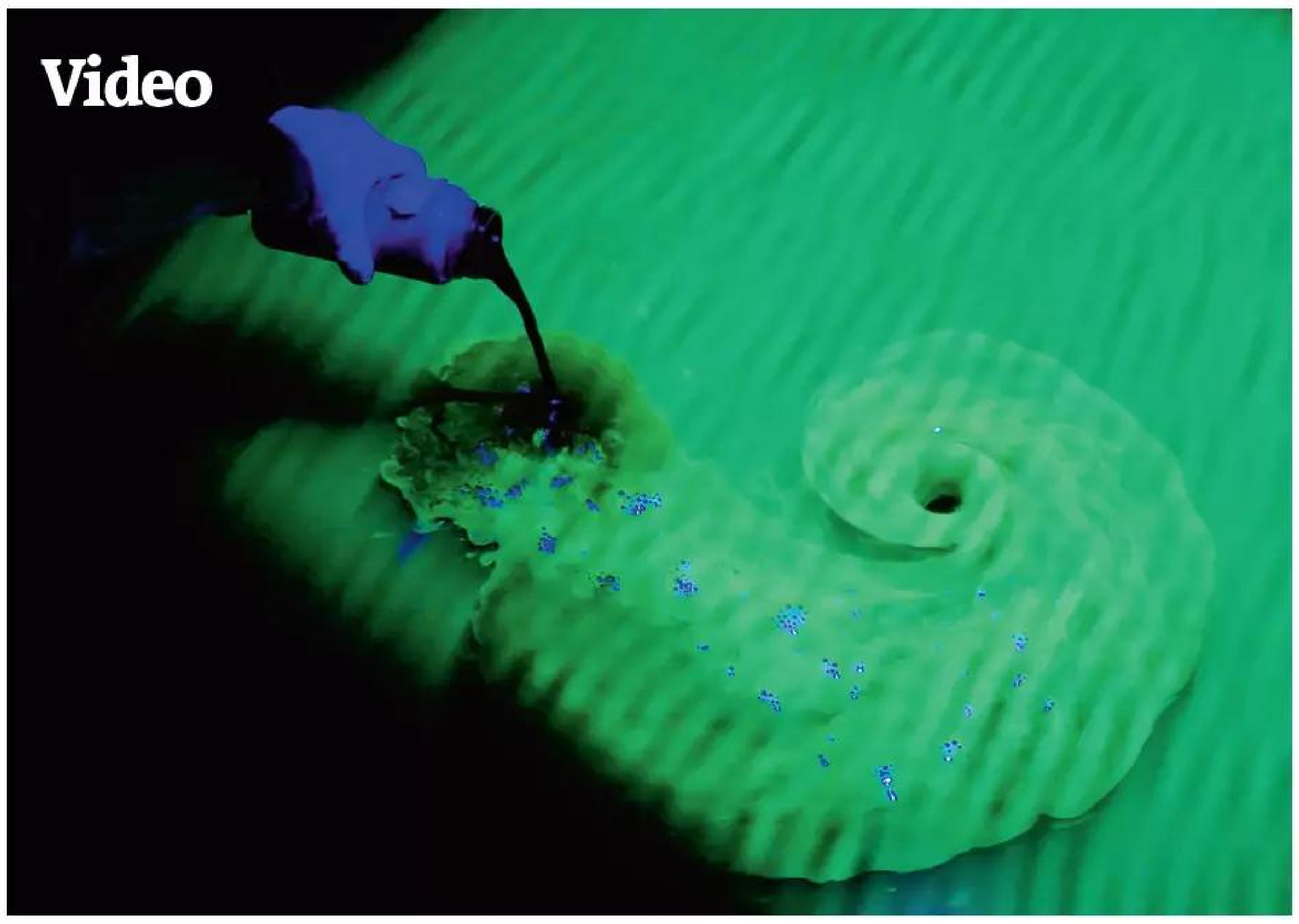
The world, the universe and us

The team discuss the effects of smartphones on teenagers. Explore the evidence surrounding signs of alien life on exoplanet K2-18b. Plus, Ersin Han Ersin, of the art collective Marshmallow Laser Feast, tells us about a digital oak tree on display at the Royal Botanic Gardens, Kew, in the UK.

newscientist.com/nspod

SHUTTERSTOCK/BORIS STROUJKO

City of science Uncover the history of modern medicine in Paris



Bath time This water tank could teach us more about black holes

Video

Liquid physics: Inside the lab making black hole analogues on Earth

Discover what bathtubs can tell us about quantum physics inside Silke Weinfurtner's laboratory at the University of Nottingham in the UK. There, a giant water tank is helping Weinfurtner and her team better understand the complexity of the universe by standing in as an analogue for black holes.

youtube.com/newscientist

Newsletter

Earth Edition

Environment reporter Madeleine Cuff rounds up all the latest climate and nature news from around the world. This month, read about a radical new plan that could raise billions to save the world's tropical forests, and the latest on a landmark climate litigation case.

newscientist.com/the-earth-edition

Newsletter

> "There are signs that the global economy may finally be starting to shift onto a greener path"

Amazing books for aspiring young scientists

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locommotion?

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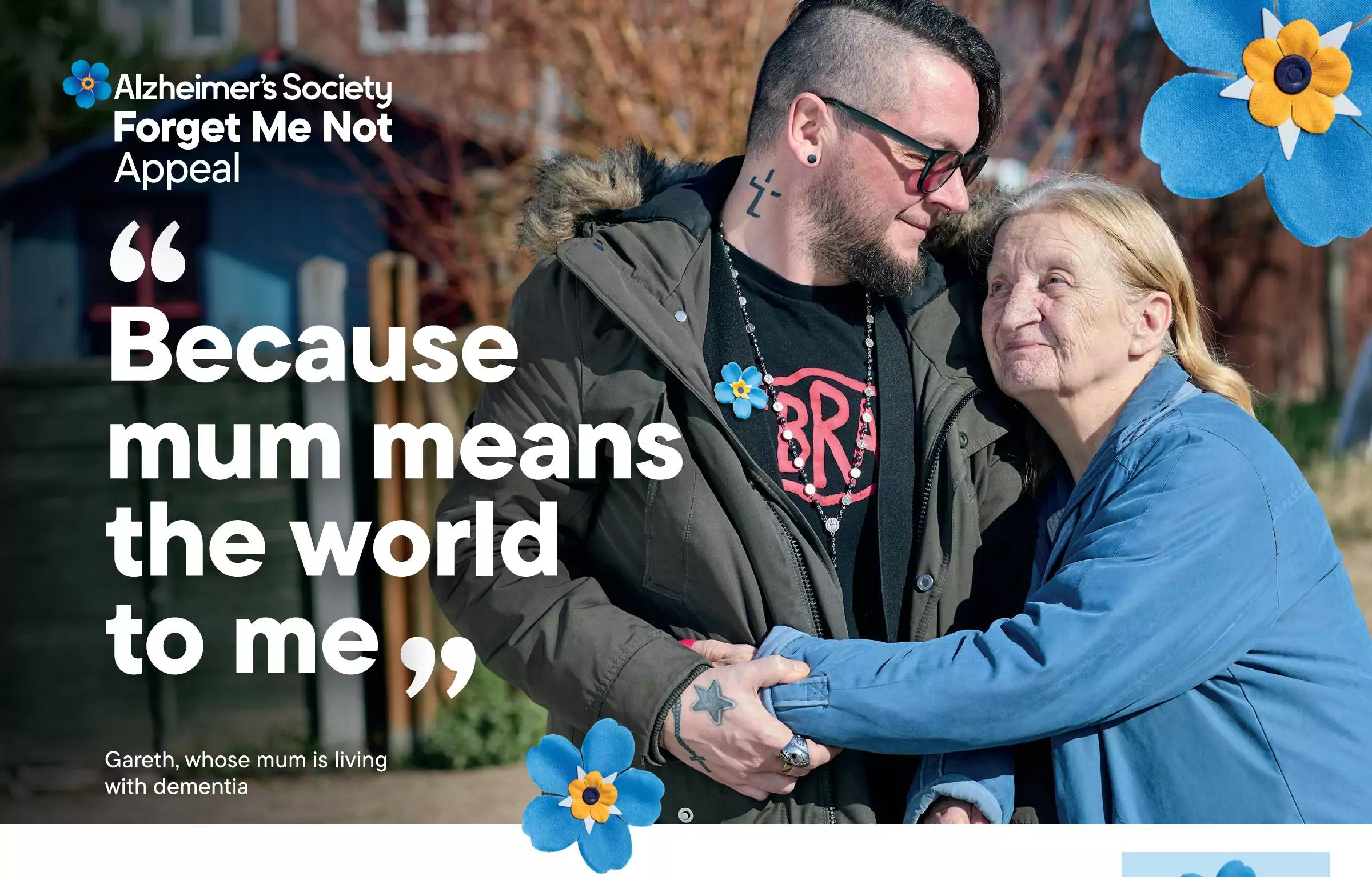

Alzheimer's Society
Forget Me Not
Appeal

“Because mum means the world to me”

Gareth, whose mum is living with dementia

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Flight of fantasy

Imagination isn't mere childhood whimsy – harnessing its power can benefit us all

"IMAGINATION is the only weapon in the war against reality," Lewis Carroll famously wrote in *Alice in Wonderland*. To the scientifically minded, in the pursuit of an ever-clearer picture of reality, such a weapon may seem of little use. Imagination might feel like the trivial stuff of childhood fairy tales and senseless daydreams. Besides, few things appear more slippery and unquantifiable than the contents of someone else's head.

The faculty, though, is something neurologists and neuroscientists are now beginning to understand in more detail and, in doing so, proving that the power of imagination isn't to be underestimated.

As we discover in this special issue, starting on page 30, we evolved our imaginative capability for a reason: it helps us to plan and empathise with others, and is the key to creative thinking.

Take the trait of "aphantasia". A decade ago, neurologist Adam Zeman coined this term to describe people with no visual imagination. Recently, several papers on the phenomenon have revealed its brain signatures. We are starting to learn more, too, about hyperphantasia, aphantasia's opposite number, in which people report an imagination so vivid it feels real. An understanding of these states of mind not only reveals deeper insights about our perception of reality, there are implications for well-being too, with hyperphantasia linked to maladaptive daydreaming – imagining scenarios and getting lost in their plot lines so often that it has a deleterious effect on a person's life.

> **"You can fine-tune your imagination and use it as a tool to achieve new goals"**

It also turns out that there are different types of imagination, and we are uncovering how it changes as we get older. What's more, we are discovering that your capacity for imagination is adaptable, and that there are ways you can fine-tune it. You can also take control of your imagination as a tool to help you achieve new goals. All this paints a picture of a powerful weapon indeed, one that can enhance joy, creativity, health and more. It is a weapon that even the most scientifically minded of us want in our arsenal. ▮

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Space

A new life on Mars? Expect toxic dust, bad vibes and insects for lunch

Steve Nelson

Earth isn't doing so great. Thanks to human-induced climate change, the seas are warming and rising, while the land – in many places – is alternately choked in drought or inundated with floods. As for us humans, we are engaged in warfare on multiple continents, far-right movements are ascendant across the world and; as of last month, "dude wipes" are available with a pumpkin spice scent in the United States.

Meanwhile, the escape hatch to space is creaking open. Elon Musk's company SpaceX has a growing fleet of cheap, reusable

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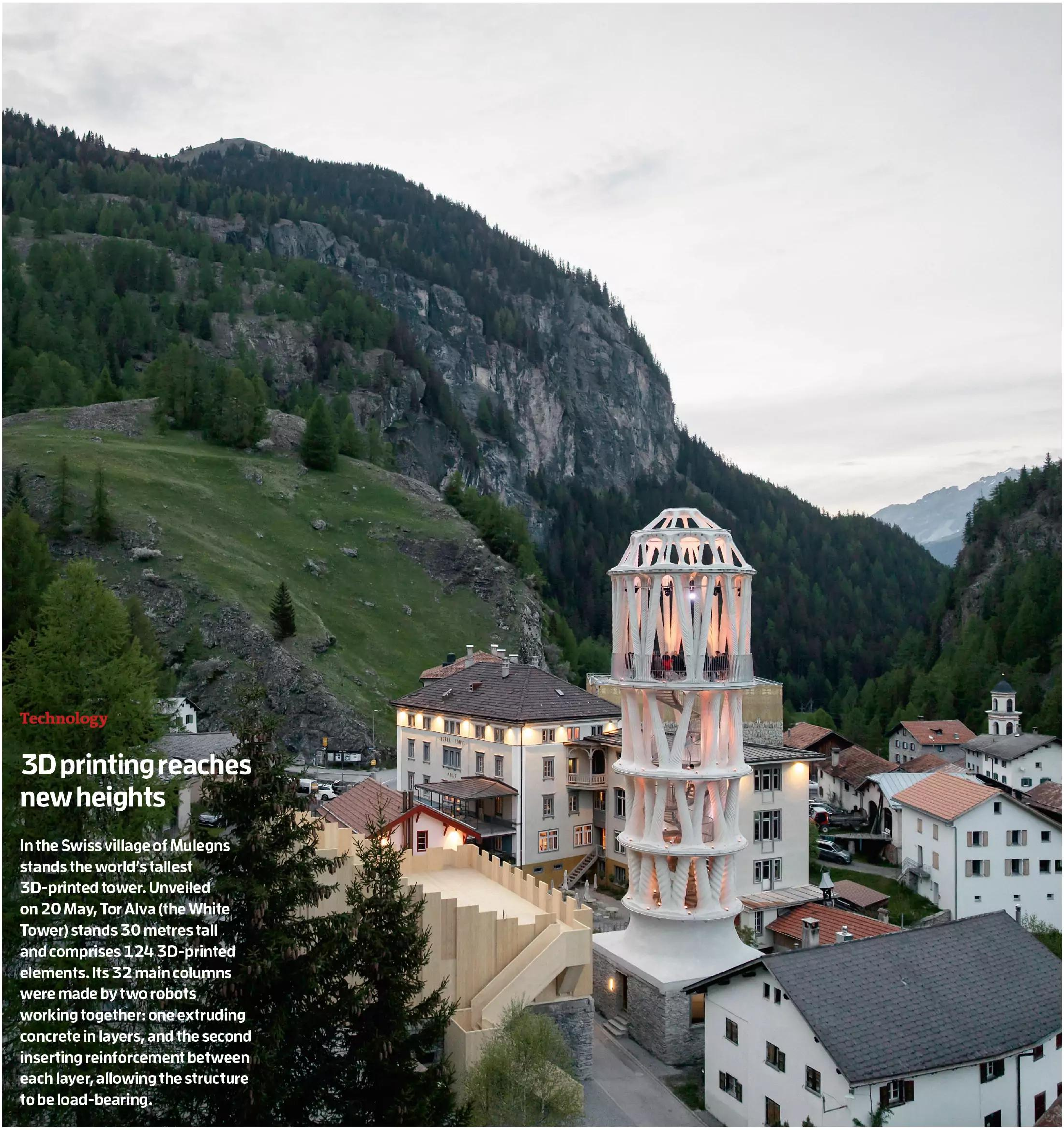
Odd orbit
We may have solved a planet's mysterious movements **p17**



Technology

3D printing reaches new heights

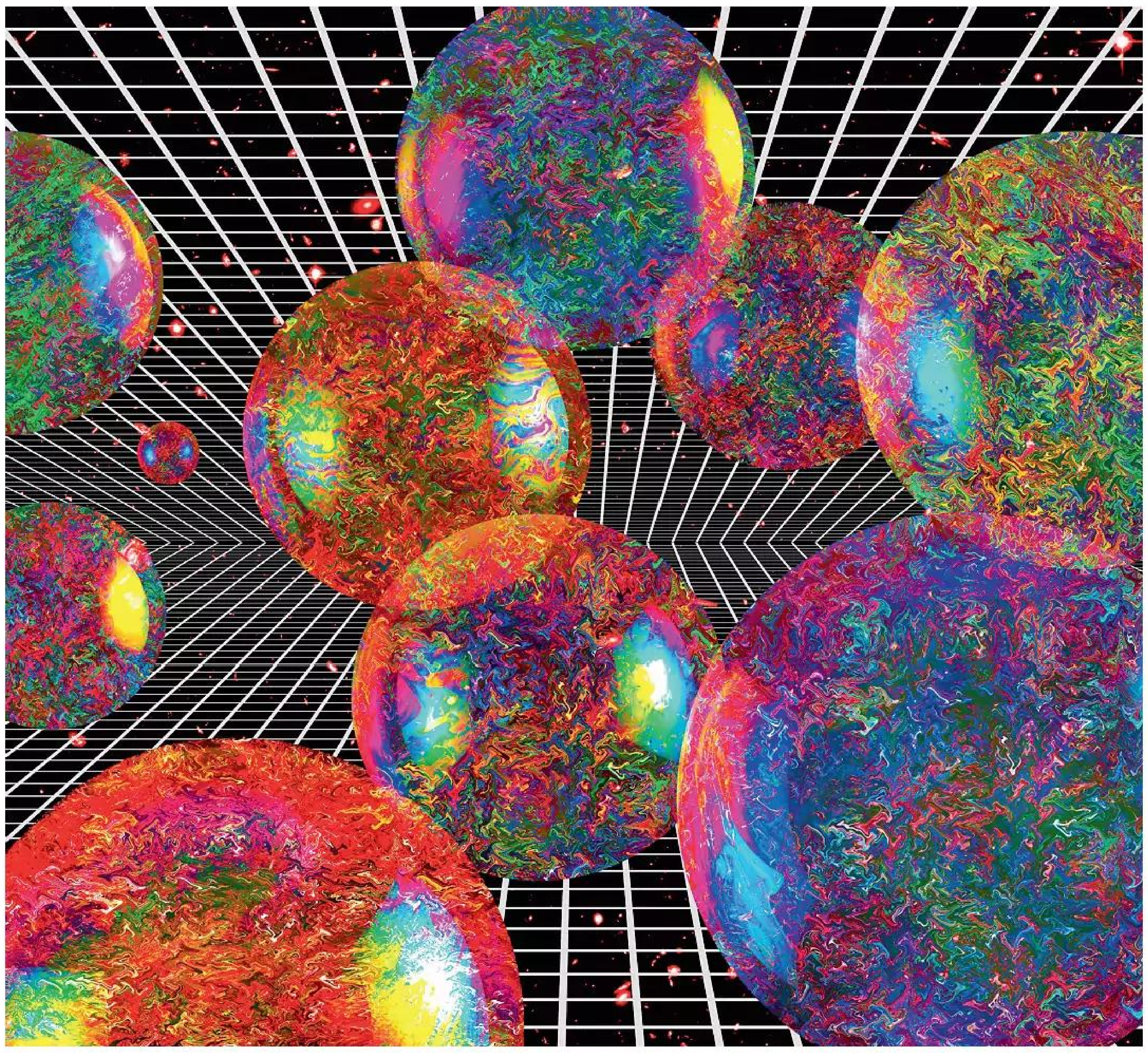
In the Swiss village of Mulegns stands the world's tallest 3D-printed tower. Unveiled on 20 May, Tor Alva (the White Tower) stands 30 metres tall and comprises 124 3D-printed elements. Its 32 main columns were made by two robots working together: one extruding concrete in layers, and the second inserting reinforcement between each layer, allowing the structure to be load-bearing.

BENJAMIN HOFER

Quantum physics

Is this the end of the multiverse?

The multiverse is derived from a particular interpretation of quantum mechanics, but now a new twist on a classic experiment says it is time to put the idea to bed, finds **Alex Wilkins**



VICTOR DE SCHWANBERG/SCIENCE PHOTO LIBRARY/ALAMY

Some physicists argue that many universes exist on top of each other

AN ADVANCED version of the famous double-slit experiment has directly measured a single photon in two places at once – or at least that is the claim made by a team of physicists who say these results could destroy the concept of a multiverse. This interpretation remains highly contested, however, with other physicists arguing that the experiment can't really tell us anything new about the nature of reality.

The double-slit experiment, first performed in 1801, has played a key role in the development of quantum mechanics. It shows that when light is shone through two thin slits, it produces a wave-like interference pattern on the other side. Bizarrely, this occurs even when particles of light, called photons, are fired through one by one, with seemingly no chance of interfering with each other.

Many physicists interpret this fact as evidence that even a single photon has a wave-like quality, which can be described by its wave function, a mathematical construct that describes all possible locations for the photon, smeared across space. In some sense, this wave-like nature allows a single photon to travel through both slits at once.

But mysteriously, placing a detector at each slit in an attempt to pin down which one the photon passes through destroys the interference pattern. The conventional view is that this is the result of the wave function "collapsing" from a measurement and localising in space, restricting the photon's ability to pass through both slits. But the true nature of the wave function – whether it really exists or is just a mathematical description of reality – is highly contentious.

For instance, some physicists argue for a "many-worlds" interpretation, where a superposition of possible universes exist on top of each other, each of which contains photons moving through different paths, and both of these paths can interfere with each other. A detector set up at one of the slits will cause reality to fork and choose one of these universes from the possible multiverse.

But now, Holger Hofmann at Hiroshima University in Japan and his colleagues claim that they have direct evidence of this photon travelling through both slits, using a more complex version of the double-slit experiment. This shows that the wave function is less of a mathematical tool and closer to what is really happening, says Hofmann.

"I do expect disagreements, because we are stepping on a lot of people's feet by actually taking sides"

"Previously, the assumption was that it's a speculation. You don't know what happens to the particle," he says. "This [experiment] really makes this totally new and even a bit provocative, because what we are saying is that there is evidence for a physical delocalisation, and it's not a speculation, it's experimental evidence."

Hofmann and his team used an interferometer, which splits a photon's wave function between two paths using a type of mirror, before both paths meet again at an exit, where two detectors measure the photon's interference pattern. Similar to the double-slit experiment, this interference suggests the photon has travelled down both arms, but again it isn't possible to measure which path exactly without upsetting the wave function.

To get around this, Hofmann and his team used a technique called weak measurement, which makes very faint recordings of a particle's properties without causing collapse and repeats an experiment many times, building up a statistical picture of the particle. Here, they added a glass plate to each interferometer arm that slightly twists the photon, changing what is known as its polarisation. The plates work in opposite directions for each path, meaning that if the photon truly did travel down both paths, then these twists would cancel out when measured at the end.

Indeed, by measuring the photon's polarisation at the two exits and comparing how often the polarisation changed in each one over many runs of the experiment, Hofmann and his team found their results matched a scenario where a single photon delocalised and travelled down both arms (arXiv, doi.org/pn9q).

"What we are claiming here is that the rate at which the photon flips its polarisation is a direct measure of the concept of delocalisation," says Hofmann. "If the photon delocalises, this flip rate goes down; that's a direct physical effect of delocalisation."

Many worlds, many views

The fact that the team could perform this measurement challenges the many-worlds interpretation of quantum mechanics, says Hofmann, because it removes the need for a superposition of different universes. "A superposition should not be confused with simultaneous parallel realities of any kind. In our case, I think we have actual evidence that this is not the case, because we are seeing an effect that corresponds to a distribution of a single photon."

Jonte Hance at Newcastle University, UK, says this could make it slightly more difficult for some physicists to argue that the wave function is a mathematical smokescreen for what is going on. “It makes it harder to believe that quantum mechanics is all just epistemic and probability distributions about real, normal things that behave like we expect them to.”

But Lev Vaidman at Tel Aviv University in Israel argues that these results can still make sense within a many-worlds interpretation, because we are only seeing the delocalisation of the photon in one possible branch of reality – there could be another branch that sees the photon travel down one path or another, which we don’t see.

“In a parallel world, [the photon] was found in another output port of the interferometer, and when it’s found in another output port, in this other world the photon was in a different arm and had a different presence,” says Vaidman.

More fundamentally, the concept of weak measurements is hotly debated by physicists, with some arguing that you can’t use repeated statistical measurements to infer properties about single particles. “I think you can’t make claims about a single photon with this,” says Andrew Jordan at Chapman University in California.

“I do expect disagreements, because we are stepping on a lot of people’s feet by actually taking sides in interpretation issues and claiming that interpretation issues could be solved by experiment,” says Hofmann. “The problem has always been that we had peace between the different interpretation camps because there was an agreement that nobody can decide, and we are claiming that experimental tests are possible.” ▮

Gene editing

Colossal scientist now admits they haven’t really made dire wolves

Michael Le Page

THE dire wolf is “the world’s first successfully de-extincted animal”, claimed Colossal Biosciences on 7 April. And many people seemed to believe it. *New Scientist* was one of the few media outlets to reject this, pointing out that Colossal’s animals are just grey wolves with a few gene edits.

Now, in a new interview, Colossal’s chief scientist Beth Shapiro appears to agree.

“It’s not possible to bring something back that is identical to a species that used to be alive. Our animals are grey wolves with 20 edits that are cloned,” she tells *New Scientist*. “And we’ve said that from the very beginning. Colloquially, [Colossal is] calling them dire wolves and that makes people angry.”

Richard Grenyer at the University of Oxford says this is a major departure from what Colossal has said previously.

“I think there is a serious inconsistency between the contents of the statement and the actions and publicity material – including the standard content of the website, not just [the] press briefing around the dire wolf – of the company,” he says.

One of Colossal’s modified grey wolves at 3 months old

COLOSSAL BIOSCIENCES

For instance, the Colossal press release announcing the birth of the gene-edited wolves refers to them as “dire wolves” throughout. Shapiro defended this claim in an interview with *New Scientist* on 7 April.

“We are using the morphological species concept and saying, if they look like this animal, then they are the animal,” she said at the time.

It is actually unclear whether the gene-edited wolves look like dire wolves. For example, there is some evidence dire wolves had reddish rather than white coats, according to Claudio Sillero at the University of Oxford.

Yet even when Sillero and other experts put out a statement saying the gene-edited wolves aren’t dire wolves, the company stuck to its guns. “[W]e stand by our decision to refer to Romulus, Remus, and Khaleesi colloquially as dire wolves,” said Colossal in a statement on X.

But in her more recent interview with *New Scientist*, Shapiro claims Colossal made it clear from the start that the animals are just gene-edited grey wolves.

“We didn’t ever hide that that’s what it was. People were mad because we were calling them dire wolves,” she says. “Then they say to us, ‘but they’re just grey wolves with 20 edits’. But the point is we said that from the beginning. They’re grey wolves with 20 edits.”

“It’s not possible to bring something back that is identical to a species that used to be alive”

Shapiro also sought to distance Colossal from suggestions that if de-extinction is possible, less needs to be done to save endangered species – a view espoused by some in the Trump administration. “Now it’s suddenly tied to this idea that we don’t have to care. It’s terrible,” she says.

Responding to this story after it was published online, a Colossal spokesperson says: “In our press release, we stated we made 20 gene edits to grey wolf cells. Grey wolves are the closest living relative to the dire wolves, as we showed in our paper. With those edits, we have brought back the dire wolf. We have been using the concept of functional de-extinction from the beginning, and that is what Colossal achieved. Those are the facts and nothing has changed.

“We have also said that species are ultimately a human construct and that other scientists have a right to disagree and call them whatever they want to call them. Khaleesi, Romulus and Remus are the first dire wolves to walk the Earth in 12,000 years.” ▮

Archaeology

Ancient temples may have been schools for celestial navigation

Taylor Mitchell Brown

SEVERAL 5000-year-old temples in Malta seem to have been oriented towards specific stars, suggesting they could have been where people learned how to navigate by the night sky.

Ancient people constructed seven temples across the Maltese archipelago from 3800 to 2300 BC. Fashioned from large, cut stones weighing several tonnes, the complexes are among the earliest megalithic structures ever built.

FELIX CHOO/ALAMY

The temple of Hagar Qim in Malta was one of those studied

"Most researchers agree that the temples display features associated with ritual behaviour," says Huw Groucutt at the University of Malta. Many contain abundant animal and human remains, suggesting that ancient people used them to host feasts or sacrifices. One site held over 220,000 human bones.

Prior research found that many of the temples share a similar orientation, facing south or south-east. One such temple, called Mnajdra, aligns precisely to fill with light during solstices and equinoxes.

While researchers have proposed many hypotheses to explain the unique orientation of the buildings, the exact explanation has been elusive.

"The temples may have been oriented at random or to follow the slope of the land," says Fabio Silva at Bournemouth University, UK. "Other hypotheses suggested the temples were built to maximise daylight or avoid strong winds."

Silva and his colleague Tore Lomsdalen, also at the University of Malta, took measurements of 32 megalithic structures on the islands of Malta and Gozo and used statistical modelling to test several hypotheses against each other, including whether the temples were oriented randomly, to avoid wind, to align with the natural landscapes or to look at certain stars in the night sky.

"We found out that none of the terrestrial explanations account for the orientation," says Silva. Instead, many temples appear to capture the rising and setting of specific southern stars, including Hadar, part of the constellation Centaurus; Gacrux, which is part of the Southern Cross; and Avior, which is part of the False Cross (*Archaeological and Anthropological Sciences*, doi.org/pn7d).

"Many temples appear to capture the rising and setting of specific southern stars"

"These stars are notable for being used for navigation purposes by a number of cultures," says Silva.

He believes the temples may be similar to "stone canoes" used by ancient Polynesian people to teach celestial navigation to young seafarers. These canoe-shaped stones were aimed at important stars and would help novice voyagers learn how to read the night sky like a map.

"Unroofed corridors [in the temples] provided the perfect simulacra of being at open sea whilst still safely inland," says Silva. "The temple entrance then framed a specific part of the horizon where these important navigational stars rose or set."

Groucutt is open to the possibility that Malta's ancient people used stars to navigate the sea, but he suspects the south-facing temples were built to maximise daylight and minimise exposure to strong northerly winds.

"Clearly, some temples were built with celestial factors in mind," says Groucutt. "However, this is seemingly an exception and not the rule."

"Only by exploring [all] options will we get a firmer grasp of the purpose of the Maltese temples as a whole," says Silva. ▮

Psychology

We assume women are morally superior to men

Sara Novak

THINK of an imaginary person who has a strong moral compass. According to recent experiments, you probably just pictured a woman or a girl. It seems we tend to associate morality more closely with femininity than masculinity, which may pose a surprising disadvantage for women.

Jordan Wylie and her colleagues at Boston College in Massachusetts wanted to understand the traits and attitudes that we ascribe to people who are considered morally good. They first had 270 people look at pairs of images of people of an unknown gender and choose who they thought looked the most moral. In 99 per cent of cases, the image that they ranked as being more feminine was also whom they considered to be morally superior.

In another experiment, a separate 282 people were presented with a list of traits, which they were asked to ascribe to either femininity or masculinity. The researchers found that traits like being angelic or peaceful were more commonly considered to be feminine, while having a challenging disposition was linked to being masculine (PsyArXiv, doi.org/pn9g).

"We see really consistent results across these studies despite them having very different methodologies," says Wylie.

To assess the effects of these associations, 1600 people were asked to judge the morality of an average man and woman, which they did again after hearing about certain moral shortcomings, such as them turning in someone else's work project under their own name.

The results suggest that women experience a greater fall in their perceived morality than men for the same transgressions, which could be interpreted as them being held to a higher standard and then being judged more for failing to live up to it, say the researchers. ▮

Solar system

China eyes ambitious space mission

Two very different space rocks – an asteroid and a comet – will be visited by a single probe

Matthew Sparkes

FINAL preparations are under way for China to launch an uncrewed craft to visit both an asteroid and a comet, in the hope of learning more about the space rocks in our solar system.

The Tianwen-2 mission by the China National Space Administration (CNSA) will collect a 100-gram sample from the asteroid Kamoʻoalewa and return it to Earth. After dropping off the sample, the probe will use our planet's gravity as a slingshot to boost itself towards the comet 311P/PanSTARRS, which it will observe remotely.

As *New Scientist* went to press the mission was due to launch from the Xichang Satellite Launch Center in Sichuan province on 29 May. It won't be the first to return samples of asteroids to Earth, as both NASA's OSIRIS-REx and JAXA's Hayabusa missions have already done that. But it will be China's first mission to an asteroid involving the return of a rock sample, and it is likely to be the first mission to a unique type of body called a quasi-satellite.

Quasi-satellites like Kamoʻoalewa don't strictly orbit Earth, but travel in a similar orbit to us around the sun, swinging elliptically around our planet as they do so. This unusual situation has led scientists to suspect that this particular one is a chunk of the moon ejected millions of years ago by an asteroid impact.

> **“The mission is daring as the asteroid Kamoʻoalewa is spinning, which will make landing harder”**

On the other hand, 311P/PanSTARRS has an asteroid-like orbit – spinning around our sun in the asteroid belt between Mars and Jupiter – but with an appearance more like a comet as it has tails. These are thought to be bits of dust and rubble flung out from its spinning body.

The CNSA has previously said that 311P/PanSTARRS is a “living fossil”, making it useful for studying the early material composition, formation process and evolutionary history of the solar system. And Tianwen-2 will provide scientists with a better understanding of both Kamoʻoalewa and 311P/PanSTARRS. The craft is due to reach 311P/PanSTARRS in 2034, and the Kamoʻoalewa sample is expected to return to Earth in late 2027.

Exactly how much the CNSA will share about the discoveries is unclear. Leah-Nani Alconcel at the University of Birmingham, UK, says the mission's outline is known, and one probable goal is to study the differences between the asteroid and the comet to gain a deeper understanding of the range of bodies in our solar system, but precise details aren't forthcoming.

Alconcel's previous experience working with the CNSA on the Double Star satellite leads her to suspect that the agency will hold on to the resulting scientific data tightly. “It was extremely difficult to negotiate [with the CNSA],” says Alconcel. ”Once they kind of had some information from us, they were not very keen to reciprocate. There will not be a public repository of this data, I don't think.”

She says that the mission is daring, as Kamoʻoalewa is spinning, which will make landing harder. Navigation algorithms are likely to demand such powerful computers that images and sensor readings will be sent back to Earth for computation.

The CNSA didn't respond to *New Scientist*'s request for interview. ▮

Evolution

How giant ground sloths evolved – then went extinct

ALBERTO BOSCAINI

These sloth skulls show the difference in body size between species

A COOLING, drying climate turned sloths into giants – before humans potentially drove them to extinction.

Today's sloths are small, sluggish herbivores, but for tens of millions of years, South America was home to a dizzying diversity of sloths, with some weighing nearly 5 tonnes.

That staggering size range is of particular interest to Alberto Boscaini at the University of Buenos Aires in Argentina and his colleagues, who compiled data on the physical features, DNA and proteins of 67 extinct and living sloth genera – groups of closely related species – to develop a family tree spanning 35 million years of evolutionary history. They added information about each sloth's habitat, diet and lifestyle, and also studied trends in body-size evolution, making body mass estimates of 49 of the ancient and modern sloth groups.

The results suggest sloth body-size evolution was heavily influenced by climatic and habitat changes (*Science*, DOI: 10.1126/science.adu0704). For instance, some sloth genera began living in trees and shrank in body size.

Meanwhile, three different lineages evolved elephantine proportions – seemingly within the past several million years, as the planet cooled and South America became more arid.

Many of these diverse sloths disappeared during two stages: one around 12,000 years ago and the other around 6000 years ago, says Boscaini. “This matches with the expansion of *Homo sapiens*,” he says.

Notably, the only surviving sloth species live in trees so are much harder for humans to hunt than massive ground sloths. ▮

Jake Buehler

Physics

Physicists battle over dark energy

The bombshell finding that dark energy may weaken over time shook physics last month. Now other physicists are challenging this view, finds **Alex Wilkins**

IS DARK energy changing, or is it just more of the same? Last month, astronomers announced the startling finding that dark energy – which is thought to cause the accelerating expansion of the universe – might weaken over time. This has forced physicists to consider upending the standard cosmological model of the universe. Now, some researchers are saying this may be premature.

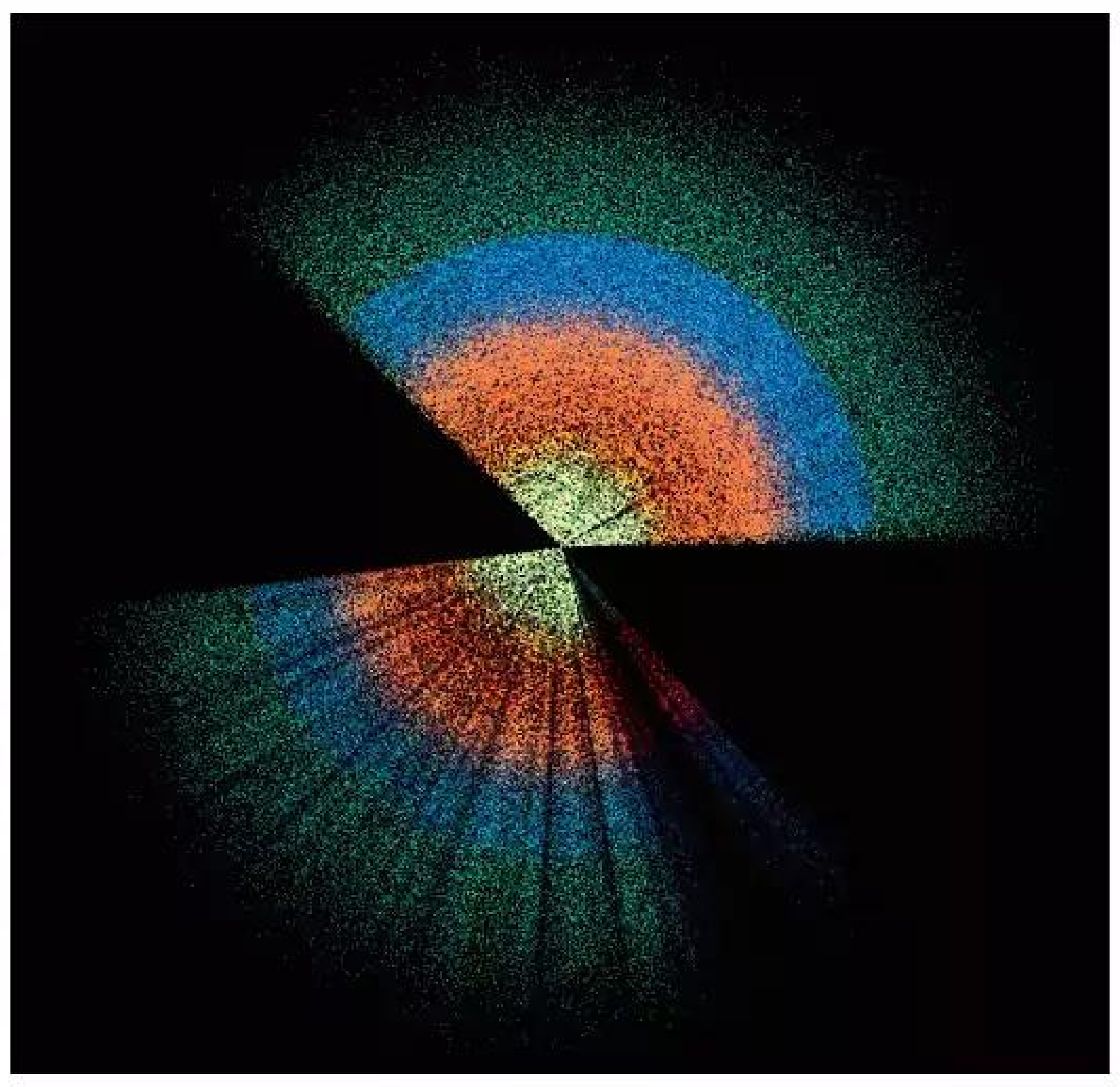
Since it started scanning the sky in 2021, the Dark Energy Spectroscopic Instrument (DESI) in Arizona has been carefully measuring the distances between millions of galaxies to better understand how our universe is changing over time.

> **"To claim that there's any evidence for evolving dark energy, you're on really thin ground"**

In April, researchers at the DESI collaboration announced that, when they combined their latest measurements with other datasets measuring how matter is distributed in the cosmos, like the cosmic microwave background (CMB) and supernovae, they found weak hints that the acceleration of the universe might be slowing.

This implies an evolving dark energy and a sharp departure from the standard model of cosmology, which is called Lambda cold dark matter (Lambda-CDM).

But George Efstathiou at the University of Cambridge, who helped lead a mission called Planck that gathered our best view of the CMB, disagrees with this conclusion and is now trying to convince the rest of the physics community to take his side.


CLAIRE LAMMAN/DESI COLLABORATION

Celestial objects are mapped by DESI, with Earth at the centre

"To claim that there's any evidence for evolving dark energy, you're on really thin ground."

To assess whether dark energy is changing, cosmologists need to measure how matter is distributed throughout the universe at different times. To do this, they look at what are called baryon acoustic oscillations (BAOs), which are echoes from the universe's first moments, when matter and energy could move more easily through space due to hotter temperatures. Like water bubbles solidified in ice, BAOs are patterns preserved in the distances between objects in space and can be used to work out how space has expanded over time.

The DESI researchers used patterns in the CMB, as seen by Planck, to map BAOs in the early universe, and they used DESI's measurements of the distances between galaxies and stars to assess BAOs as they appear today. They also used data on supernovae to provide another measure of how space has expanded.

By combining these, the researchers could assess whether the data was best explained by predictions from Lambda-CDM or from a model containing evolving dark energy. They concluded that the evolving dark energy model worked slightly better.

But Efstathiou argues that this difference becomes apparent only when the supernova data is included in the analysis – and based on his experience with this dataset, he thinks it isn't accurate enough to be used in this way. "The strongest evidence for evolving dark energy is coming from a catalogue where I think you can actually see that there are systematic errors," he says.

Efstathiou also argues that the DESI team's Bayesian statistical analysis, which involves assigning "prior" probabilities to which model is more accurate before adjusting these to reflect the data, gives too much weight to the evolving dark energy model (arXiv, doi.org/pn9k). Since we have other lines of evidence that Lambda-CDM is correct, our prior probability should be higher than for the evolving model, he says.

"I agree with his conclusions," says Mathias Zaldarriaga at the Institute for Advanced Study in Princeton, New Jersey. "I don't think the DESI results necessarily point to an evolving dark energy with any significance."

An evolving argument

Zaldarriaga also thinks comparing models isn't as simple as giving them both equal weighting, as DESI has done, because a more complicated model might be able to better fit the data without being more physically plausible. "You don't necessarily have to believe it," he says.

In a private meeting this month, Efstathiou presented his analysis to DESI researchers, who he says disagree with his arguments.

"We've looked at what Efstathiou did, and he hasn't indicated to us that we need to change our analysis in any way, so that's good," says Will Percival at the University of Waterloo in Canada, speaking on behalf of the DESI collaboration. "He obviously has a strong interpretation of the data, but that seems more subjective than quantitative and based on statistical reasoning."

The next release of DESI data is due as early as next year. "If I'm right, the evidence will not strengthen," says Efstathiou. "That's a very definite prediction. If they were really onto something, then you'd expect something to show up." ▮

KPNO/NOIRLAB/NSF/AURA/P. MARENFELD

The DESI survey is being carried out at Arizona's Kitt Peak National Observatory

Environment

Piles of penguin poo help keep Antarctica cool

James Dinneen

FUMES of ammonia from droppings in Antarctica's crowded penguin colonies help boost the formation of clouds, which have a cooling effect by reflecting sunlight.

"This demonstrates a deep connection between the ecosystem and atmospheric processes," says Matthew Boyer at the University of Helsinki in Finland.

In order to form a cloud, water vapour must condense around a particle of some kind. But these are hard to come by in Antarctica. Without much dust, vegetation or air pollution, most of the particles available for a would-be cloud are clusters of sulphuric acid molecules generated as a result of natural emissions from phytoplankton in waters around the continent.

High concentrations of ammonia were already known to accelerate the formation of these clusters a thousand-fold. To see if penguin droppings were a rich source, Boyer and his colleagues measured concentrations of ammonia, sulphuric acid and larger particles in the air several kilometres downwind of a 60,000-strong colony of Adélie penguins (*Pygoscelis adeliae*) on the Antarctic Peninsula. "They smell terrible," says Boyer. "They're dirty birds."

When wind was blowing from the direction of the colony, the team found ammonia concentrations rose far above the levels found in air arriving from other directions. This rise in ammonia also boosted the formation of particles of sulphuric acid large enough for water to condense around them, and, presumably, to form clouds. This effect persisted for weeks after the penguins had moved on from the colony (*Communications Earth and Environment*, doi.org/pn9d).

More clouds, especially over the ocean, would have a cooling effect by reflecting sunlight away from Earth's surface. ▮

Analysis Health

Are microplastics in ultra-processed foods harming your mental health?

A bold proposal links two of the biggest health issues of our times, but is it correct, asks **Carissa Wong**

ULTRA-PROCESSED foods (UPFs) and microplastics have one thing in common: we don't actually know if or how they harm our health. But researchers have now proposed a link – UPFs might contain high levels of microplastics that worsen mental health.

How plausible is this idea, and can it be tested? Nicholas Fabiano at the University of Ottawa in Canada and his colleagues say their hypothesis hinges on a few key strands of emerging evidence.

SHUTTERSTOCK/SIAMIONAU PAVEL

Your burger and fries may contain some extra ingredients

The first is that UPFs contain high levels of microplastics. While defining a UPF is a murky business – some argue it includes anything that can't be made at home – it is generally taken to mean foods made mostly from ingredients extracted from other foods or synthesised in labs. These can include cookies, soft drinks and breakfast cereals.

Such industrial processing is likely to expose food to plastic machinery, conveyer belts and packaging that shed microplastic fragments – pieces that are less than 5 millimetres long – argue the researchers (*Brain Medicine*, doi.org/pn9p). Supporting this, the team points to a recent study that found highly processed protein products contain more microplastics than less-processed ones – for instance, chicken nuggets contain 30 times more microplastics than chicken breasts.

"It is very, very plausible that the more processed the food is, the more chemical contaminants and microplastics it's bound to have," says Jane Muncke at the Food Packaging Forum, a non-profit organisation based in Switzerland.

But she says we don't yet have enough evidence to say this definitively – the study highlighted by Fabiano and his colleagues only looked at 16 foods and only a handful of similar studies have been conducted, so larger studies are needed, she says. What's more, even if UPFs are generally rich in microplastics, that doesn't mean all of them are, or that all unprocessed foods are low in microplastics, she says.

The next piece of the puzzle is whether UPFs harm mental health. Fabiano points to a review of observational studies that looked at UPF intake and mental health symptoms across 10 million people. It found that those who consumed high levels of UPFs had about a 20 per cent higher risk of depressive symptoms and were around 50 per cent more likely to experience anxiety compared with those whose diet contained no or low levels of UPFs.

> **"It is plausible that the more processed the food is, the more microplastics it's bound to have"**

While this suggests a link between UPFs and poor mental health, untangling causation is tricky. For instance, people with poorer mental health may be more likely to eat UPFs, rather than the other way around, says Fabiano.

Stronger evidence comes from about half a dozen randomised controlled trials. In these, people with depressive symptoms were randomly assigned to either eat their usual diet or switch to a Mediterranean one low in UPFs. Those who cut down on UPFs saw greater improvements in depressive symptoms.

Finally, if it turns out that UPFs do harm mental health, how likely is it that microplastics within them are to blame, rather than their nutritional content? There isn't yet evidence connecting microplastics to mental health outcomes, says Michael Berk at Deakin University in Australia. That's partly because it is so hard to accurately measure their levels.

"You've got to make sure you're not contaminating samples with the lab equipment," says Joe Yates at the London School of Hygiene & Tropical Medicine. Nevertheless, figuring out whether microplastics play a role in mental health – and to what degree – is crucial, he says. ▮

Technology

US military eyes world's largest plane

Jeremy Hsu

WINDRUNNER/RADIA

The WindRunner could carry other planes, as shown in this concept art

AN AIRCRAFT designed to carry giant wind-turbine blades, which will be the largest plane ever built, is being explored for military use.

The WindRunner, under development by the company Radia in Colorado, is planned to have an 80-metre wingspan and a 108-metre length. That is roughly the dimensions of a FIFA-regulation football field, giving the aircraft about 12 times more cargo volume than a Boeing 747 airliner and a maximum payload of 72,575 kilograms.

The WindRunner was designed at this scale to deliver 100-metre-long turbine blades to remote wind farms in the continental US. But its massive cargo capacity could have other uses, says Kenneth Bibb, Jr., vice president of business development for defence at Radia.

The US Department of Defense signed an agreement with Radia to study how the WindRunner could carry military cargo such as vehicles, oversized equipment and even smaller planes. The military isn't yet providing any funding for WindRunner's development.

One reason for the military's interest may be Radia's claim that the WindRunner could land on and take off from dirt airstrips as short as 1800 metres. "With its ability to land on short, unpaved runways, it will provide flexibility in times of humanitarian crisis and combat," says Bibb.

But Greg Malandrino at the Center for Strategic and Budgetary Assessments, a defence policy think tank in Washington DC, says this feat – and other manoeuvres like getting into position to load and unload cargo – will be "very challenging" if the world's largest aircraft travels to austere airstrips in remote locations.

Adapting a specialised wind-turbine carrier to become a multi-role cargo aircraft is also difficult, though not impossible, says Malandrino. The WindRunner's proposed range of 2000 kilometres with a full payload could prove most useful for shorter airlift missions between military air bases that have typical paved runways within North America, South America or Europe. If the design enables aerial refuelling, a capability that the US military's current heavy cargo aircraft already have, that would enable the WindRunner to operate from locations further afield. ▮

Evolution

Teeth may have come from ancient fish skin

Michael Marshall

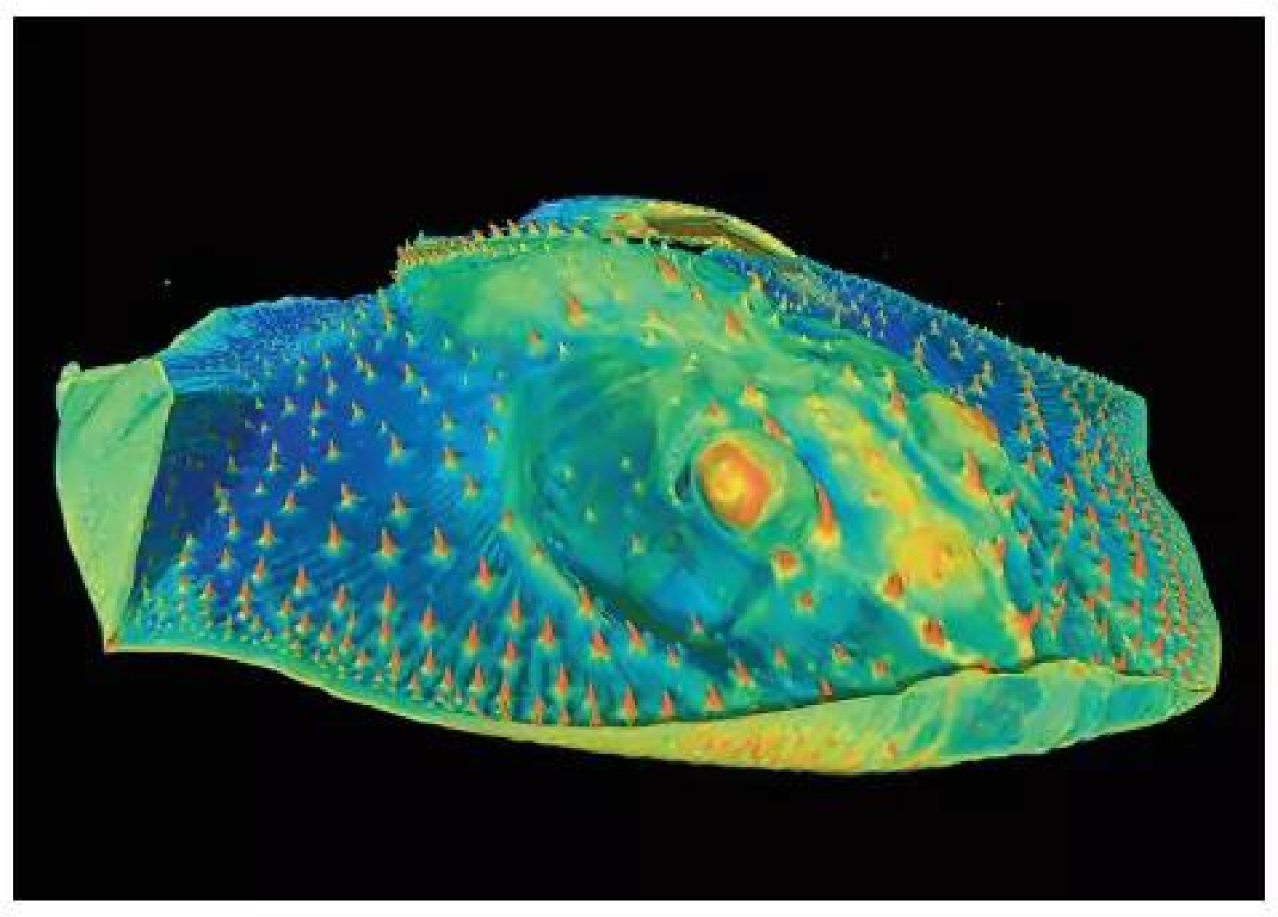
THE first tooth-like structures evolved not for chewing or biting, but instead as sensory nodules on the skin of early fish.

The finding supports a long-standing idea that teeth first evolved outside the mouth, says Yara Haridy at the University of Chicago.

True teeth are only found in backboned vertebrates, like fish and mammals. Some invertebrates have tooth-like structures, but the underlying tissues are completely different. This means teeth originated during the evolution of the earliest vertebrates: fish.

Haridy and her team re-examined fossils that have been claimed to be the oldest examples of fish teeth, using a synchrotron to scan them in unprecedented detail.

They focused first on fragmentary fossils of animals called *Anatolepis*, which date from the later part of the Cambrian Period, which ran from 539 million to 487 million years ago, and early in the Ordovician Period, which ran from 487 million to 443 million years ago. These animals had a hard exoskeleton, dotted with tubules, thought to be made of dentine, one of the hard tissues that make up teeth.



YARA HARIDY

This CT scan shows tooth-like denticles (in orange) on skate skin

In human teeth, dentine is the yellow layer under the hard white enamel and it performs many functions, including sensing pressure and pain.

This led to the idea that the tubules are precursors to teeth called odontodes and that *Anatolepis* is an early fish.

"These animals needed to sense their way through the muck of ancient seas"

After examining structures from a range of animals, Haridy and her team found that the tubules were most similar to features called sensilla found on the exoskeletons of arthropods like insects and spiders (*Nature*, doi.org/g9kwmq). These look like pegs or small hairs and can detect "everything from taste to vibration to changes in air currents", says Haridy.

This means *Anatolepis* is an arthropod and its tubules aren't the direct precursors to teeth. With it out of the picture, the team says, the oldest known teeth are those of *Eriptychius*, from the Ordovician Period. These do have true dentine – in odontodes on their skin.

Haridy says invertebrates like *Anatolepis* and early vertebrates like *Eriptychius* independently evolved hard, sensory nodules on their skin. "These two very different animals needed to sense their way through the muck of ancient seas," she says. The team found that the odontodes on the skin of some modern fish still have nerves, suggesting a sensory function.

Once some fish became active predators, they needed a way to hold onto their prey, so the hard odontodes made their way to the mouth, where they could be used to bite. ▮

Entomology

Bees have a power line problem

Airborne electric fields seem to have a dramatic effect on honeybee foraging

Madeleine Cuff

ELECTRIC signals from power lines discourage bees from landing on nearby flowers, and there is growing concern that this so-called "electric pollution" could be causing widespread disruption to insect behaviour.

Alongside bumblebees, honeybees have been shown to detect and respond to airborne electric fields – which are often caused by static electricity in the natural world – detected through hairs or antennae. Honeybees use electroreception as a form of communication, and both honeybees and bumblebees are thought to use it to locate nectar-rich flowers.

But to date, little is known about how human-generated electricity impacts this natural behaviour among pollinators.

To investigate, Liam O'Reilly at the University of Bristol, UK, and his colleagues team tested how the behaviour western honeybee (*Apis mellifera*) changed when different kinds of electric fields were applied to the air around a catmint plant (*Nepeta grandiflora*) in an urban meadow in Bristol.

They created an electric field using a weak alternating current (AC), simulating the environment 60 to 100 metres from a high-voltage mains power line, for 2 hours. This reduced honeybee landings on the affected plant by 71 per cent compared with a nearby control plant.

"The first 10 minutes of the AC treatment was a really dramatic difference – there were far fewer landings than the control," says O'Reilly. "Alternating current is just completely alien to bees." Landings did increase on the treatment plant as the trial continued, but never reached control levels, notes O'Reilly.

These beehives may need to be moved somewhere else

IGOR STEVANOVIC/ALAMY

In another test, the team created an electric field using direct current, like the power generated by a battery, reducing landings by 53 per cent compared with the control (*iScience*, doi.org/pn4h).

The findings have worrying implications, especially given the ubiquity of electricity infrastructure in most nations. Estimates suggest that in the UK alone, there are almost 70,000 square kilometres of land on which bee colonies forage in the range of high-voltage transmission lines.

Other studies have shown that honeybee behaviour is affected by human-made electromagnetic fields, but this is the first to isolate the impact of electricity, says Sam England at the Museum of Natural History Berlin in Germany. The study "confirms a lot of the suspicions we had already about these power lines being able to affect insect behaviour", he says.

More research is needed to determine how power lines and other electricity infrastructure are changing insect behaviour in real-world settings, says O'Reilly, including whether behaviour is altered over the long term.

"In the short term, if you're someone who has an apiary, it would probably be better if you can keep your apiaries further from power infrastructure," says O'Reilly. "I think you'd have happier bees." ▮

Technology

Contact lenses let you see infrared light even in the dark

PEOPLE have been able to see beyond the visible light range thanks to novel contact lenses, picking up flickers of infrared light when it is dark – or when they have their eyes closed.

The lenses contain engineered nanoparticles that absorb and convert infrared radiation – specifically, a near-infrared wavelength range of 800 to 1600 nanometres – into blue, green and red light visible to the human eye. That is the same trick night-vision devices use to help people see in the dark, but the contact lenses weigh much less and require no power.

"The contact lenses would provide military personnel with discreet, hands-free night-vision capabilities that overcome the limitations of bulky night-vision [goggles or scopes]," says Peter Rentzepis at Texas A&M University, who has done related research applying the same nanoparticles – sodium gadolinium fluoride, ytterbium and erbium – to eyeglass lenses.

The new wearables, developed by Yuqian Ma at the University of Science and Technology of China and his colleagues, don't provide detailed night vision yet. That is because they can pick up only "high-intensity, narrowband LED" light sources, says Rentzepis, rather than lower levels of infrared light from ambient sources.

"It's an audacious paper, but, using just the contact lens, you wouldn't be able to read a book in the infrared or navigate down a dark road," says Mikhail Kats at the University of Wisconsin-Madison.

"The contact lenses would provide military personnel with discreet, hands-free night-vision capabilities"

Instead, in tests on humans and mice, the contacts converted a normally invisible flash of infrared light into what Kats says should be a "big colourful blob of visible light". Those blobs had uses, however.

For example, Ma and his colleagues varied the frequency, number and colour of different light flashes to encode and transmit letters of the alphabet (*Cell*, doi.org/g9k25s). ▮

Jeremy Hsu

Artificial intelligence

AI doesn't understand the word 'no'

The inability of AI models to recognise negation words could limit their medical applications

Jeremy Hsu

TODDLERS may swiftly master themeaning of the word "no", but many artificial intelligence models struggle with commands that contain negation words such as "no" and "not".

That could mean medical AI models failing to distinguish between an X-ray image labelled as showing "signs of pneumonia" and one labelled as showing "no signs of pneumonia".

It might seem surprising that today's sophisticated AI models would struggle with something so fundamental. But "they're all bad [at it] in some sense", says Kumail Alhamoud at the Massachusetts Institute of Technology.

Alhamoud and his colleagues compiled thousands of captioned image pairs where one image contains an object and the other is missing the same object.

They focused on 10 different versions of the CLIP model, which was developed by OpenAI and combines language understanding with imagery analysis, along with an 11th vision-language model developed by Apple called AIMV2. Two versions of CLIP had been trained to interpret medical images by separate groups of researchers.

"In clinical applications, negation of information is critical to rule out certain diagnoses"

First, the researchers asked the AI models to retrieve images of certain objects and found they could do this around 80 per cent of the time. But when asked to fetch images containing these objects but not others – such as pictures of tables without chairs – the models' performance dropped to about 65 per cent or lower.

The second test challenged the AI models to select the most accurate caption for an image of a scene from a choice of four options. The versions of CLIP trained on medical images were asked to choose between just two possible options to describe medical conditions in X-ray images – forinstance, one described as showing evidence of pneumonia and another stating there is no pneumonia. The best-performing models achieved around 40 per cent or lower accuracy (arXiv, doi.org/g9j5rx).

Both vision-language models and the large language models used in AI chatbots are based on the transformer model originally developed by Google researchers. Transformer models "are really good at capturing context-specific meaning" among strings of words, says Karin Verspoor at the Royal Melbourne Institute of Technology in Australia. But "not" and "no" work independently of context-specific meaning and "can appear in many places within any given sentence", she says.

"In clinical applications, negation of information is critical – knowing both what signs and symptoms a patient has and what they can be confirmed not to have is important to characterise a condition, and to rule out certain diagnoses," says Verspoor.

Specifically training vision-language models on negation word examples improved their information retrieval performance by 10 per cent and on the multiple-choice questions by 30 per cent.

But this doesn't address how such models work in the first place, says team meber Marzyeh Ghassemi at MIT. "A lot of the solutions that we come up with are a little Band-Aid-like in nature, because they don't address the fundamental problem," she says. ▮

Ornithology

Why birds decorate their nests with foreign objects

A magpie with a quail egg stolen from an artificial nest

MAGNE HUSBY

BIRDS may fill nests with artificial objects to deter magpies and ravens from taking their eggs.

Many birds have been observed placing human-made articles in their nests, such as plastic or wires. Often, these things seem to have no role as insulation or structural support, and may even make nests more conspicuous to predators.

Magne Husby at Nord University and Tore Slagsvold at the University of Oslo, both in Norway, suggest the use of unusual materials might help in defending nests from corvids such as magpies and ravens. Both birds are notorious egg thieves, but studies suggest they have an aversion to unfamiliar objects.

"We imagined nest decoration should have a positive effect and one reason could be that corvids were sceptical of novel objects and hesitated to rob such nests," says Husby.

They also proposed that birds place large feathers on their nests to scare eggs thieves into believing a bird has been killed there.

To test these ideas, Husby and Slagsvold used three types of artificial nest. One simply contained quail eggs; another had eggs and a shiny metal spoon and the last contained eggs and large feathers. They conducted 78 trials in a forest to measure the responses of Eurasian magpies (*Pica pica*) and 60 trials at a landfill site to study common ravens (*Corvus corax*).

On average, magpies waited 96 hours before taking eggs from standard nests, 149 hours before stealing eggs from nests with a spoon and 152 hours before approaching nests with feathers.

Ravens waited 28, 34 and 43 hours, respectively (*Royal Society Open Science*, doi.org/pn6v).

This hesitation could be crucial, giving birds more time to defend their nests and protect their eggs. ▮

Sarah Philip

Space

Weird planet is orbiting backwards between two stars

Karmela Padavic-Callaghan

WE MAY have finally solved how two stars can maintain a stable orbital dance with an elusive planet.

In 2004, David Ramm at the University of Canterbury in New Zealand spotted a mysterious repeating signal while observing the motion of a pair of stars in a system called Nu Octantis. This started a long debate on whether the signal was evidence that this system included a planet roughly twice the size of Jupiter, which some physicists thought impossible because of the size and closeness of the two stars. Now, Ramm and Man Hoi Lee at the University of Hong Kong and their colleagues have offered the most conclusive evidence yet that Nu Octantis really is a three-part system.

The key observation is that the Nu Octantis planet is moving in retrograde – the planet and one star both orbit the second star, but in opposite directions, with the planet having the tighter orbit around the second star (*Nature*, doi.org/pn6h). Lee says this is unusual but stable, even though it means the planet is moving through a narrow space between the two stars.

The researchers could determine this thanks to improved measuring devices, such as the HARPS spectrograph at the European Southern Observatory telescope in Chile.

They also found that one of the stars is a white dwarf, which means it has reached the end of its life cycle, becoming denser and smaller. Lee says that, according to mathematical models, the planet's current orbit was impossible when this star was younger and bigger.

So, the planet either used to orbit both stars at once, but then radically shifted trajectory when one of the stars became a white dwarf, or it was formed from the mass the star ejected as it transformed at the end of its life. Both scenarios are rather novel, says Lee.

Climate change

Meeting 1.5°C temperature target won't stop sea level rise

Michael Le Page

MICHAEL S. NOLAN/ALAMY

Ice loss in Greenland is accelerating at an unprecedented rate

A SEA level rise of several metres is predicted over the coming centuries, even if countries are successful in their goal of limiting global warming to 1.5°C above the pre-industrial baseline.

"I think sometimes there's a misunderstanding that 1.5°C will mean all our problems go away," says Chris Stokes at Durham University in the UK. "It should absolutely be our target, but in no sense will it slow or stop sea level rise from melting ice sheets."

The world is currently on course for roughly 2.9°C of warming by 2100. That would lead to the loss of both the Greenland and West Antarctic ice sheets, says Jonathan Bamber at the University of Bristol in the UK. "So if we're talking about long-term commitments, that's in excess of 12 metres of sea level rise," says Bamber.

Stokes, Bamber and their colleagues have reviewed three lines of evidence: satellite observations of ice loss and sea level rise over the past three decades; studies of warm periods in the past; and computer models of ice sheets.

Early computer models, which didn't include many key processes, suggested that ice sheets would take a long time to respond to warming, says Bamber.

In fact, the satellite observations show that the Greenland and West Antarctic ice sheets are responding rapidly.

> "Tipping points might exist, but every fraction of a degree really matters for ice sheets"

"The observations show a very different picture," says Bamber. "Some of the mass loss we've seen in Greenland has been really quite staggering, really unprecedented in comparison to what the models had predicted."

Not only are Greenland and West Antarctica already losing ice, the trend is accelerating, says Stokes.

"And all of this is happening at just 1.2° of warming," he says. "So the idea that 1.5 is going to somehow fix this problem is misleading."

Studies of previous warm spells during the past 3 million years show that the sea level was many metres higher during these periods, says Stokes.

The last report by the Intergovernmental Panel on Climate Change (IPCC), published in 2021, predicted 1 to 2 metres of sea level rise over many centuries if the increase in temperature was limited to 1.5°C, says Stokes.

"We're bringing that forward," he says. "It's very clear now that, actually, we're starting to see some of those worst-case scenarios play out almost in front of us in terms of the satellite record of mass balance."

To merely slow sea level rise from the melting ice sheets to a manageable level, the average global temperature needs to be reduced to around 1°C above the pre-industrial baseline, the team estimates (*Communications Earth & Environment*, doi.org/pn3k).

While higher-income countries can defend their coasts against rising sea levels, it will get harder and more expensive as the seas keep rising, says Bamber. "And then, of course, there'll be some countries that just haven't got that money."

This is why taking action is so important, says Stokes. "Every fraction of a degree really matters for ice sheets," he says. "Yes, tipping points and thresholds might exist, but I think sometimes they can distract from the basic knowledge that actually every fraction of a degree really matters."

Technology

Do phones harm teens? Who knows

A "consensus statement" on the effects of smartphone use among adolescents has been accused of failing to actually reach a consensus based in evidence, finds **Chris Stokel-Walker**

JEFF GREENBERG/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

The effect of smartphones on teenagers is still unclear

AN ATTEMPT to reach a scientific consensus on the potential harms posed by smartphones and social media use in young people has descended into an argument among researchers. This failure to come to an agreement suggests it will be difficult for policy-makers to lean on existing evidence when deciding how to regulate such technologies.

Valerio Capraro at the University of Milan-Bicocca in Italy and more than 100 colleagues, drawn from 11 different disciplines, have published a "consensus statement" on the potential negative effects of smartphone use on adolescents (PsyArXiv, doi.org/pnwq).

"We've been following the discussion about the debate, and we thought that maybe we could try to find a common ground between different viewpoints," says Capraro.

The researchers analysed 26 detailed claims about smartphones' impact on teenagers' mental health, such as that heavy use can cause sleep deprivation or behavioural addiction.

These claims were drawn from *The Anxious Generation* by Jonathan Haidt at New York University, a book that has been influential in the debate over smartphones, but also heavily criticised by some researchers. Haidt himself is also a co-author of the statement.

Each researcher then individually rated whether they agreed with each claim, as well as the strength of evidence supporting it. There was broad agreement on several critical points: 99 per cent agreed that adolescent mental health had declined notably in the US, with similar trends in other Western nations, and 98 per cent concurred that heavy smartphone use correlates strongly with sleep disturbances.

More than 94 per cent of the experts surveyed agreed that young girls encountered particular issues, including unduly comparing themselves to peers, feeling the need to look perfect and being exposed to online sexual harassment.

However, the experts also agreed in similarly high proportions that the evidence for these claims is only correlational, not causal. More rigorous research, including longitudinal studies tracking smartphone users over time, would be needed to prove a correlation, many agreed.

Overall, while more than 90 per cent agreed something was wrong with young people, only 52 per cent supported policy actions like age restrictions on social media use and phone bans in schools.

Despite that caveat, the researchers suggest that shouldn't be an excuse for inaction by policy-makers. "Obtaining high-quality causal evidence of the effectiveness of policy decisions often takes years, whereas policymakers often have to make decisions in rapidly changing environments with limited data," they wrote.

> **"We thought that maybe we could try to find a common ground between different viewpoints"**

But researchers who weren't involved with the consensus statement have disputed its findings, and it has also drawn criticism on social media.

For example, Pete Etchells at Bath Spa University, UK, points out that only around 120 of the 288 invited experts from across various disciplines took part in the process.

He suggests that those who believe smartphones have a negative impact on adolescents would be more likely to opt in to a survey like this – thus skewing the outcomes.

"I'd like to see them account for potential expert biases in their dataset," he says. "I don't think they do this."

A hotly debated topic

Etchells, who has also written a book on the subject, wonders how those 288 initially invited experts were selected: "I know I wasn't contacted about this at any point."

Sonia Livingstone at the London School of Economics also disagrees with the researchers selected to form a consensus: "The long list is meant to provide a sense of balance, but it mainly lists those on one side of the argument. If science is not balanced, it is nothing."

Capraro defends the diversity of the panel, saying that "thousands of people are working on these topics around the world", and that "it's not feasible to contact them all".

He says: "We analysed several indicators and provided multiple converging lines of evidence that our expert sample is diverse with respect to several dimensions, and we found no evidence of missing viewpoints."

Questions of who took part aside, Livingstone also takes issue with the claims examined. "The problem is that it's a biased set of questions. They don't ask, 'Is there also evidence social media can improve mental health or friendships or a sense of belonging?' There is also evidence for those," she says.

Capraro says the aim of the research was to "represent as many viewpoints as possible" on a "very hotly debated topic". ▮

Space

Astronomers double down on claim of strongest evidence for alien life

Alex Wilkins

THE researchers behind the bold claim that we have recently seen chemical signatures of life on a distant exoplanet say they have yet more evidence for molecules with no origin outside of biology – but critics say this new work undermines the original efforts.

In April, Nikku Madhusudhan at the University of Cambridge and his colleagues announced their remarkable finding that K2-18b, a super-Earth 124 light years away, showed "strong evidence" for an atmosphere containing the molecules dimethyl sulphide (DMS) and dimethyl disulphide (DMDS) – both of which, on Earth, are produced solely by life. Ever since, astronomers have been closely scrutinising their findings.

Jake Taylor at the University of Oxford showed that applying a different statistical test indicated there was little evidence for DMS. In a separate paper, Luis Welbanks at Arizona State University and his colleagues found that Madhusudhan and his team didn't consider many alternative molecules that may fit the data, and that when the molecular pool under consideration is expanded from the original 20 to 92, then DMS is no longer the only explanation.

Now, Madhusudhan and his team have gone far beyond that, comparing the chemical signatures of 650 different molecules to what they see in the spectrum of light from K2-18b's atmosphere. They found that an additional two molecules, diethyl sulphide and methyl acrylonitrile, fit the data just as well as DMS. Both are complex molecules that also have no non-biological origin on Earth (arXiv, doi.org/pn3f).

K2-18b, shown here in an artist's impression, is 124 light years away

A. SMITH/N. MANDHUSUDHAN

Madhusudhan says this new analysis is the most comprehensive chemical search of an exoplanet atmosphere ever performed and that it strengthens his team's claim, because the new molecules are even harder to explain than DMS – both in their origin and chemical complexity – making it more likely that DMS is the best explanation for what they see. "After our most recent work, I am slightly more confident," he says.

But Welbanks disagrees, and says it is notable that the DMDS detection has disappeared from the new results. "DMDS is no longer included among the highlighted species, despite being central to the original claim," he says.

Madhusudhan, however, says that their original claim didn't rely upon DMDS, and the fact that DMS still remains in their data is consistent. "It had never been that we were saying it was only DMS that we were picking up. We are just saying now that it is DMS or even more complex molecules that we're picking up," says Madhusudhan.

Taylor says the Cambridge team's new analysis is more statistically rigorous than their initial work. However, he disagrees with Madhusudhan's interpretation that DMS is the most likely interpretation, and argues that the results show the data isn't currently precise enough to determine exactly which molecules are present. ▮

Health

Stimulating vagus nerve could help spinal cord injuries

PEOPLE who are partially paralysed from spinal cord injuries have regained some movement thanks to vagus nerve stimulation, along with physical therapy.

Michael Kilgard at the University of Texas at Dallas and his colleagues surgically implanted a device that electrically stimulates the vagus nerve into 19 people who had incomplete cervical spinal cord injuries. This is when damage to the spinal cord in the neck blocks some nerve signals between the brain and upper extremities, reducing hand and arm function.

The participants also underwent 18 physical rehabilitation sessions, involving exercises such as finger pinching and wrist twisting.

Vagus nerve stimulation was given to 10 participants within 1 second of completing an above-average movement, in terms of its force, speed, accuracy or fluidity. The rest received it at random. Hand and arm function was assessed using a standardised test.

Eight of those receiving targeted stimulation saw a 23 per cent reduction in movement limitations from their initial scores, on average – while no one in the control group did (*Nature*, doi.org/g9kwj7).

Kilgard says targeted stimulation probably worked better because it releases neurochemicals that help strengthen and form neural pathways. That release coming after an above-average movement may reinforce it, he says.

"Participants made gains on things they wanted to do in everyday life, such as putting on a necklace"

All participants then received 18 sessions of targeted stimulation, after which average pinch force improved by almost 400 per cent and wrist torque by 152 per cent.

"These people didn't just make gains on metrics for the clinical trial, they made gains on things they wanted to do in everyday life", such as putting on a necklace, says team member Jane Wigginton, also at the University of Texas at Dallas.

Kilgard and his team are planning a large, late-stage trial – the last step before submitting a therapy for regulatory approval. ▮

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Views

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A snake-gathering ceremony that aids conservation **p24**

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Culture columnist
Bethan Ackerley is a reluctant *Murderbot* convert **p28**

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Mind-melding with a bat raises many questions **p29**

Comment

The science of violence

We need to learn from an ingenious study in the Stockholm subway and radically change policies around violent crime, says **Jens Ludwig**

SIMONE ROTELLA

NEARLY half a million people are murdered around the world every year. While the means vary across nations – knives in Australia and the UK, guns in the US and Mexico – what is universal is the sense of hopelessness about these deaths. Yet there is a solution, one that comes from an unexpected source: the subway system of Stockholm, Sweden.

Since a solution can only be unexpected in relation to some conventional wisdom, it is useful to start by looking at how we have typically thought about the problem of interpersonal violence.

In most countries, right-of-centre political parties tend to think violent crime stems from intrinsically bad people who are unafraid of the criminal justice system. That has led to policies that try to disincentivise violence through ever-harsher punishments.

Left-of-centre parties tend to think violence stems from bad economic conditions, that it is committed by desperate people who need to feed their families. That has led to policies that try to disincentivise violence by improving alternatives to crime, like jobs and income support.

Interestingly, both sides implicitly agree that violence stems from a premeditated, deliberate weighing of pros and cons. It is, as my late University of Chicago colleague Gary Becker put it, rational. No wonder so many policies focus on disincentives.

This view of violence turns out to be wrong, according to an ingenious study by economist Mikael Priks. It looks at a sort of natural experiment created by the installation of surveillance cameras in Stockholm subway stations at different times from 2006 to 2008. This means we can see if crime declined more in the stations that got cameras early relative to those that got cameras later on. The data shows that the installation of cameras reduced crime overall by 25 per cent.

The key insight, though, comes from looking at what types of crimes were, or weren't, affected. Property crimes declined, but violent crimes didn't. The lesson is that deterrence works, but mostly for income-motivated crimes, which are the ones that tend to be premeditated and (relatively speaking) rational.

Deterrence works much less well for interpersonal violence because so much of it isn't premeditated. Most violence stems from in-the-moment arguments when people aren't thinking about the consequences of their actions. No wonder disincentives don't help.

In my new book, I argue that we should heed the lessons of this Stockholm subway study and radically reorient our policies around violence prevention.

We need to recognise that violence is usually a crime of passion, not profit. For solutions, we must stop looking exclusively at the idea from neoclassical economics of perfectly rational people, and start looking towards behavioural economics instead.

What would that look like? One of the most important lessons from behavioural economics is that our deviations from rational behaviour have some predictable structure. That includes emotional, violent behaviour. This has allowed us to develop social programmes to help people better understand their own minds and how to prevent emotions taking over, as well as policies to get more trained adults out in public to defuse conflicts. The impacts are large – depending on the policy, 20 per cent, 30 per cent, even 50 per cent decreases in violent crime – while the costs are typically low.

Most progress in the human condition for things like life expectancy or material well-being has tended to come from scientific breakthroughs. The good news is the same pattern could potentially hold – if we pay attention to the data and the evidence – for one of our most seemingly intractable social problems as well. ▮

Jens Ludwig is the author of *Unforgiving Places: The unexpected origins of gun violence*

This changes everything

Storms ahead New AI models are set to revolutionise weather prediction. But as our climate becomes more extreme, we need to ensure broad public access to their forecasts, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest book is *Stories Are Weapons: Psychological warfare and the American mind*. They are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is techsploitation.com

"IT'S an absolutely unbelievable scientific achievement," says Andrew Charlton-Perez, talking to me by video from his office at the University of Reading, UK. His colleague, Simon Driscoll at the University of Cambridge, nods enthusiastically. "There are so many different applications and so many different uses for it."

No, they aren't referring to quantum computing or nuclear fusion. They are talking about weather prediction. "People just moan about the weather forecast and how bad it is," says Charlton-Perez. As a meteorology professor, he hears this a lot. But that is because most people don't realise that our ability to predict the weather, given the complexity of the atmosphere, is practically a superpower. "This is an incredibly complicated system that we don't observe very well. And we can put it onto your phone and it's pretty accurate most of the time," he says.

Driscoll, a maths and physics researcher, has spent a lot of time working with Charlton-Perez on the miracle of "pretty accurate" forecasting. They have sliced and diced the many petabytes of weather data accumulated since the 1990s by satellites, weather balloons, ships and ground sensors. Now, they are testing new AI models that could change the way we predict the weather. No, you moaners, it isn't going to become perfectly accurate. But it is about to change how you learn if tomorrow will be sunny.

Some big scientific insights of our time came from attempts to predict the weather. Edward Lorenz discovered chaos theory while modelling atmospheric circulation. He knew the way a storm develops is both chaotic and highly dependent on initial conditions. Lorenz fed those initial conditions into an early digital computer, using variables like temperature and wind speed. He found that a tiny shift in one of those variables led to a wildly different prediction of the storm's path. He called it "deterministic chaos". In popular parlance, it is known as the butterfly effect.

Every time you get a weather alert on your phone, it is partly thanks to Lorenz and partly thanks to a daily analysis produced by national and international weather centres. For their starting variables, they use meteorological data gathered by thousands of sensors, on Earth and in orbit, and then feed it into a large computer, which spits out pretty accurate forecasts of the sort that tell you there is a "30 per cent chance of rain". This is known as numerical weather prediction and it has ruled the roost for decades.

> "We could be about to democratise access to weather prediction, which would help smaller countries"

The problem is that it requires expensive supercomputers to ingest huge amounts of current weather data, compare it with past events and subject all of it to the rules of physics to get an idea of what will happen. Global teams have cooperated to produce your rain forecast. Driscoll, for example, has contributed expertise on how ocean ice is affecting the climate. Ultimately what this means is that only a few countries can afford to generate weather reports, leaving most of the world dependent on the generosity of a small number of government agencies.

All of that could change with new AI models. In a paper last year, Charlton-Perez and Driscoll stress-tested four popular AI models to see how well they could predict an unusual stormy event known as a bomb cyclone. They did decently, but "the big difference is that it's thousands of times faster", says Charlton-Perez. Plus, "the forecasts we used… I ran them on my laptop".

So AI could potentially allow forecasters to predict weather with fewer resources and smaller teams, meaning less dependence on, say, the US or the European Union for information about the temperature in Barbados. We could be about to democratise access to weather prediction. This would help smaller countries, but would also allow anyone to track niche weather phenomena. If you love rainbows, you could ask an AI model to predict where the next one might appear.

Still, Charlton-Perez warns there may be new roadblocks. The input data required to make a forecast has traditionally been shared freely. But as the cost of analysing it comes down, "the data becomes even more king than it was", he says. He worries that firms behind AI weather models, such as Google, Microsoft and Nvidia, might enter into exclusivity relationships with meteorological services for such data. In other words, much of the globe would be dependent on tech companies for weather reports instead of government bodies.

Worse still, it could cut public access to free forecasts at a time when we need it most. Heat waves are getting deadlier. Storms that were once inconvenient now cause killer floods. This worries Charlton-Perez, who believes meteorological prediction is humanity's "primary climate change adaptation tool". In an era when extreme weather is on the rise, we need to know what is coming. Having that information may increasingly be the difference between life and death. ■

Annalee's week

What I'm reading

Historian Josephine Quinn's In Search of the Phoenicians, *because I want to understand the Punic world.*

What I'm watching

Murderbot*!!! Need I say more?*

What I'm working on

Getting ready to visit Knossos – one of the great Bronze Age city-states – on the island of Crete in Greece.

This column appears monthly. Up next week: Rowan Hooper

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Saintly serpents

Piero Castellano

EVERY year on 1 May, San Domenico di Sora gets some spectacularly bizarre accessories. During a religious procession in the Italian village of Cocullo, a statue of the saint is adorned with harmless snakes (far left). The origins of this *festa dei serpari,* or festival of the snake-catchers, may date back centuries.

Gianpaolo Montinaro, a biologist at the University of Bari Aldo Moro, Italy, was eager to study the snakes, but it took him years to convince the villagers that a long-term research project would help, rather than harm, the reptiles. Legally, the *serpari* can only catch local snakes, such as green whip snakes (*Hierophis viridiflavus*) and four-lined snakes (*Elaphe quatuorlineata*, shown far left and bottom, near left), in the weeks up to the procession. Shortly after, the animals are released (top, near left) at the exact spot where they were found, which leaves little time for Montinaro and his team to study them.

Before each procession, the researchers transform the local museum into a pop-up health clinic for snakes. They measure each animal's length and weight, take swabs and blood samples, and implant microchips to identify repeat visitors. They also treat wounds and remove parasites from the snakes' bodies and mouths (bottom, near left).

Almost 20 years' worth of data indicates the snakes are thriving, with no sign of a dangerous fungal disease that has appeared in other European populations. We might benefit as well. "Snakes pick up microbes on the ground," says Montinaro. "That helps us to look out for novel pathogens that could infect humans." ▮

Susanne Wedlich

Time for bed

Can anthropology and biology help babies sleep better? A new book has some fascinating insights but is somewhat impractical, says **Penny Sarchet**

Book

How Babies Sleep

Helen Ball

Cornerstone Press (UK); Balance (US)

WESTEND61 GMBH/ALAMY

LIKE many mothers of young children, I have spent a lot of nighttime hours reading about baby sleep on the internet. I'm fluent in the lexicon – from wake windows to split nights – and the frustratingly impossible exhortation to "put your baby down drowsy but awake".

I approach all these concepts as I would in my day job – looking for evidence, or at least some semblance of scientific plausibility. Both can be hard to come by.

So it was with excitement that I picked up *How Babies Sleep: A factful guide to the first 365 days and nights* by anthropologist Helen Ball, hoping to finally get the level of scientific detail I had been looking for. I came in with three questions: Is it true that babies' sleep cycles are around 40 minutes? Why are overtired babies so difficult to get to sleep? And what causes the sudden, disruptive "sleep regression" parents often see at around 4 months?

The book partially delivered. Throughout, Ball details many changes in sleep that occur around the 3-to-4-month mark, yet she is keen to dismiss the notion of sleep regressions. A chapter on sleep biology, however, did confirm that 3-to-6-month-old babies have sleep cycles of 45 to 60 minutes in length, vindicating advice I had read suggesting that if a baby wakes around 40 minutes into a nap, they may just be slipping into their next cycle and won't necessarily be ready to get up.

As for overtiredness, Ball explains how a baby who won't go to sleep can be one of two things – either not tired enough (in which case you would be better off giving up and taking them on a walk), or tired enough but not sufficiently relaxed to give in to sleep. That certainly explains why "overtired" babies need more comforting before they nod off – but while Ball dispatches with the common idea that "sleep breeds sleep", I was still left wondering whether babies who have had enough naps in the day might be better able to wind down in the evening. It seems logical, but throughout the book, Ball suggests quite a relaxed approach when it comes to daytime sleep – "allowing babies to nap on the go as and when they need to".

"Ball suggests abandoning crib-based naps, but I found they were essential to keep up with chores"

In fact, Ball suggests that abandoning crib-based naps can be "incredibly liberating", whereas I found they were essential for keeping up with all the cooking, cleaning and laundry. Her solution to this conundrum is to draft in friends and family – alloparents, as they're known in anthropology – to help. This has a long evolutionary history, but I'm not sure how it can work if your friends and family aren't nearby, or have other things to do.

For a book intending to guide parents through the first year of sleep, I was surprised at how many pages were given over to the benefits of co-sleeping. Ball has done much research into how families bed share in countries like the UK, where the practice isn't as prevalent as it is in most of the world.

The conclusions of her and others' research are, from an evolutionary perspective, fascinating. For example, mothers and babies who share a bed sleep in very different ways from those who sleep apart, particularly those who breastfeed. There's a syncing of arousals and a lightness of sleep that may, possibly, be beneficial for babies' brain development, and that gives mothers a "heightened awareness of their presence".

Does napping more during the day lead to a better night's sleep for babies?

That doesn't sound particularly restful for mum, though. And the book's heavy emphasis on co-sleeping is unfortunate for other reasons, too. While it is becoming clearer how to safely bed share, there are many factors, detailed in the book, that can make the practice less safe and rule out this option for your family.

I have no problem accepting Ball's assertions that co-sleeping is globally and historically the more normal thing to do, but I had hoped for much more guidance on alternative ways of sleeping. Instead, much of the useful information is squeezed into 17 pages of frequently asked questions at the end of the book, with not enough space for the scientific detail I was hoping for.

Frustratingly, Ball concludes: "how your baby sleeps over the course of their first year can happen in whatever ways work for you and your baby". I just wish there was more evidence to help us find these ways. ▮

Our dark materials

Extracting Earth's resources is a rich story shot through with awe, power, greed and hubris, finds **Adam Weymouth**

Book

Under a Metal Sky

Philip Marsden

Granta (UK, on sale)

Counterpoint (US, 4 November)

TRAVEL writer Philip Marsden lives on the river Fal in Cornwall, UK. About 3500 years ago, after a little tin was added to copper and the Bronze Age was set in motion, vast quantities of tin from the mines inland made their way down this river, across to Europe and beyond. As copper had and iron later would, bronze revolutionised our lives. It shaped how we fought, traded and lived – so much so that experts talk of "bronzisation" as the beginnings of globalisation.

In his new book, *Under a Metal Sky: A journey through minerals, greed and wonder*, Marsden follows those trade routes, pushing east across Europe in this engrossing history of the metals and rocks that underpinned what we call progress.

In the Netherlands, we see how unregulated peat-cutting in the past transformed the nation's fortunes, but ultimately opened the country up to flooding by the sea, the common sense of leaving the land intact no match for the insatiable thirst for energy. And in the Harz mountains in Germany, at one of Europe's first major silver mines, Marsden explores the legacy of excavation in the local poisoning of the land and the global economy that the metal set in motion.

Via Slovenia's mercury mines and the radon spas of Austria, we come at last to the Georgian mountains, where men have panned for gold in the same rivers for centuries.

Marsden spent his childhood rock collecting, and he is familiar with the addiction of the quest and the discovery. His tale is of our enduring fascination with the world, our collective curiosity and awe as we sought out gems and rocks that would transform how we related to it.

He is especially drawn to the ideas of visionaries whose imaginations were fired by these subterranean wonders: people like Goethe, whose time in Germany's silver mines led him to perceive the whole world as interconnected and ever-changing, and Rudolph II, Holy Roman Emperor in the 16th century, who was a rock-collector and patron to a vast team of alchemists who sought to penetrate the universe's mysteries.

But as much as these rocks have brought out the best in us, their rarity and finitude has always been a challenge to creatures who struggle to keep their greed in check. The story of any resource is a tale of hubris, of how everything becomes a poison when it is consumed without restraint. The more these materials liberated us, the faster we devoured. As the scientific method won out over the world view of the alchemists, writes Marsden, it became easier to separate the part from the whole, to ignore consequences. Humans persisted in drinking radium for its supposed health benefits, even as their bones crumbled. They persisted in sending men down mercury mines, even as they coughed themselves to death.

If we could understand our lust for these materials, suggests one archaeologist working in Georgia to Marsden, we might understand everything we need to know about who we are. While the technologies might adapt, as Marsden examines in a coda on lithium, the impulses remain the same as when we first grubbed up ochre out of the ground and daubed it on our bodies.

Perhaps we are transitioning from fossil fuels into an "age of metals", but, as Marsden writes, at some of the world's largest lithium mines in South America, the water courses are polluted, the water table is depleted and the local people remain in poverty. Goethe's Faust realised long ago that our unchecked transformation of the world could only lead to disaster. But there are those who still refuse to believe that nature will ultimately be calling in a reckoning. ■

Sunset over the ruins of Wheal Coates in Cornwall, once among the UK's most important tin mines

DAVID CHAPMAN/ALAMY

Adam Weymouth's new book, *Lone Wolf*, is published this month

New Scientist recommends

David Stock

Head of editorial video

London

If, like me, you are a bit of a cartophile, then **From Streets to the Stars: 500 years of maps** is for you. It is a small but perfect exhibition at the Weston Room of the Maughan Library, King's College London, until 28 September 2025, showcasing historically significant maps lurking in the library's collection, like this celestial chart from 1551, above.

DAVID STOCK

There's also Galileo Galilei's treatise *Sidereus Nuncius*, displayed open at a map of the Pleiades star cluster, drawn from rigorous observations. It is in good company next to a book by Johannes Kepler showing an extraordinarily accurate plotting of a supernova, now known as SN 1604, or Kepler's Supernova.

Plus, there is a section on medical maps with a 1903 study of sleeping sickness. This reminded me of the key role of data visualisation in the covid-19 pandemic.

There is even a *New Scientist* film on how the University of Oxford's Bodleian Library is using digitisation to investigate the late medieval Gough Map of Britain.

The TV column

Inner circle *Murderbot* fans will be thrilled to learn that the cyborg security unit that gains free will by hacking its governor module is now the star of a compelling adaptation. **Bethan Ackerley** has unexpectedly joined their ranks

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. Follow her on X @inkerley

TV
Murderbot
Apple TV+

APPLE TV+

Murderbot (Alexander Skarsgård) just wants to be left alone

FRIENDS and colleagues spent years trying to get me to read *The Murderbot Diaries*, a sci-fi series by Martha Wells about a cyborg security unit that gains free will. I resisted. They pitched it to me as quirky, which raised my hackles, or as comfort reading, which sent them skyrocketing. Not my sort of thing, I thought snootily.

But once Apple TV+ said that it would be adapting *All Systems Red*, the first instalment, I knew I had to give it a read. It was a mixed experience: the snarky humour wasn't for me and the human characters blurred together, but there was something compelling there, if I could let go of my hauteur – and the new TV series is exactly where I found it.

Murderbot (as it named itself) just wants to be left alone. As a SecUnit owned by the Company, it must do what its human clients ask – except that it has hacked its governor module and can now disobey. Murderbot has continued to perform its duties to avoid discovery and hasn't achieved much with its freedom, unless you count watching thousands of hours of television – which I most certainly do.

> “Murderbot hasn't achieved much with its freedom, unless you count watching hours of TV – which I do”

The latest humans to hire Murderbot (played by Alexander Skarsgård, but we will get to that) are scientists hoping to survey a little-explored planet. Mensah (Noma Dumezweni) and her crew hail from the Preservation Alliance, a free-loving polity outside the hyper-capitalist Corporation Rim. Unlike Murderbot's former clients, who barked orders or maimed it for fun, they ask how it is feeling and are uncomfortable with its lack of free will. Murderbot, in turn, is uncomfortable with their discomfort.

Disaster is certain to strike such an amiable bunch of spacefaring hippies. Soon enough, Murderbot is forced to protect the team from an enormous insectoid alien, acting a little too human in the process and raising the suspicions of Gurathin (David Dastmalchian). When a neighbouring survey mission goes dark, Murderbot is drawn into a perilous rescue attempt that could blow its cover.

Initially, I wasn't sold on the TV version of this story, either. I would have much rather been watching *The Rise and Fall of Sanctuary Moon*, the bombastic space opera Murderbot follows religiously. Quickly, though, I realised that the series had struck an excellent balance, faithfully adapting *All Systems Red* while layering in elements from later in the *Diaries*.

Most of the new details flesh out Mensah and her crew, such as a subplot that sees couple Pin-Lee (Sabrina Wu) and Arada (Tattiawna Jones) add a third, Ratthi (Akshay Khanna), to their relationship. For me, the new additions mostly round out the world in ways I found missing from the book, while maintaining its breezy pace.

The cast of *Murderbot* is also great, particularly Dumezweni and Dastmalchian – but, for some, Skarsgård is the elephant in the room. Murderbot has no gender and is consistently referred to as “it”, allowing readers licence, and many imagined someone very unlike the clearly masculine-looking actor in the TV series.

To those fans worried about this casting, do keep an open mind. Skarsgård is a brilliant comic actor who wrenched far more laughs from me than the novella achieved.

I have reluctantly come to appreciate the series and its surprisingly poignant story. It turns out *Murderbot* is my sort of thing, after all. ▮

Bethan also recommends...

Book
A Psalm for the Wild-Built
Becky Chambers

This is another novella I was hesitant to read because of its cosy reputation, but the world of Dex, a tea-serving monk, and the robot they meet in the wilderness is beautifully written. It warmed my cold, cold heart.

Film
I'm Your Man
Maria Schrader

In this charming romance, Alma (Maren Eggert), a scientist, must live alongside Tom (Dan Stevens), a robot who has been designed to be her perfect match.

Editor's pick

Mind-melding with a bat raises many questions

10 May, p 22

From Wai Wong,
Melbourne, Australia

I am curious to know what will happen if my mind is melded to that of a bat, a prospect raised in Rowan Hooper's latest imagined history of future inventions. Will I fall in love with its mate, crave insects and become nocturnal and fearful of owls? Will I get motion sickness when its senses mix with mine? How will I perceive light polarisation and sonar? Will I get PTSD if it gets traumatised or killed? I definitely wouldn't be one of the first to try it.

An explanation for the honest placebo effect

5 April, p 20

From Susan Eckenwalder,
Toronto, Canada

Since the effects of an illness are easily compounded by the psychosomatic pain of thinking it is worse than it actually is, there may be a reasonable explanation for finding that a placebo works even if you know you are taking it. Maybe just knowing a doctor thinks you are well enough to take a placebo rather than "real medicine" is enough to convince you that you are indeed better than you thought, thus reducing your stress-induced pain.

Why climate action by those at the top is vital

26 April, p 22

From Dyane Silvester,
Arnside, Cumbria, UK

Graham Lawton's piece on the failure of governments and corporations to support climate action was sad, but unsurprising, reading. Perhaps the best way to encourage private individuals to take practical action is to lead by example: the people telling us what we should be doing could be seen to do those things. When will we see parliamentarians personally contributing (maybe via a pay cut) towards the cost of insulation, solar panels and heat pumps for parliament, and more of them taking the train or a bike? How about corporations investing profits in solar and heat pumps for their premises? A lot of visible investment by our leaders might make us more inclined to follow.

Is current theory of dark energy beyond salvation?

10 May, p 8

From Adrian Smith,
Addingham, West Yorkshire, UK

I read "Time for a new model of the universe", which reported findings on dark matter that throw our current cosmological model into doubt. Last year, I was at a meeting at the Royal Society. In summary, it found serious discrepancies in the theory of dark energy. This was a top-level meeting with many leading individuals in cosmology, from the past and present. It feels like the meeting never took place because the issues raised are being sidelined. Rather than deal with them, some cosmologists appear to be coming up with ever more ad hoc additions (new parameters, quintessence, thawing gravity, fifth force) to shore up a failing theory.

Trial of new Lyme drug might prove tricky

3 May, p 11

From Stephanie Woodcock,
Carnon Downs, Cornwall, UK

Brandon Jutras's hoped-for trial of the antibiotic piperacillin for human Lyme disease may rely on finding a sufficient cohort of people who get an early diagnosis. Many don't, leaving them at risk of an incomplete treatment response. Moreover, it is concerning that the antibiotic primarily used now, doxycycline, could have been replaced with a superior, safe alternative long ago. Better late than never, I guess.

Anyone who says they can spot a liar is probably lying

10 May, p 43

From Sam Edge,
Ringwood, Hampshire, UK

I enjoyed David Robson's advice to the reader who worried about being gullible. He is right to point out that we are generally unable to tell if someone is lying in casual conversation. The reader might also be reassured by research showing that even those whom we might expect to be better at this, like law enforcement personnel, are equally hopeless even after supposedly science-based interrogation training. Operators of the non-scientific "lie detector", or polygraph, test have also been shown to be mistaken – with both false positives and false negatives – so often as to make their conclusions virtually worthless.

Pursuit of fossil fuel firms in court doesn't add up

3 May, p 21

From Jon Hinwood,
Melbourne, Australia

I share no glee in the story of a Peruvian farmer suing a fossil fuel firm. The logic of suing such companies for climate change damage is the same as going after arms manufacturers for deaths caused by their weapons. The person who pulls the trigger causing a death is the principal offender. The average person – with their SUV, 24/7 air conditioning and a new iPhone – is pulling the trigger in the case of fossil fuels. However, suing the energy producers will have a small, perverse benefit, as it will add to the cost of energy via fees to lawyers, slightly reducing our zeal to maximise energy consumption.

More reasons to worry about school air quality

10 May, p 19

From Dave Holtum,
Bathampton, Somerset, UK

Your report on the effect of air quality on school attendance highlights the possible impact of particulate matter on children's health. Another factor to consider is the carbon dioxide level in the classroom. Research indicates cognitive abilities can decrease by 15 per cent at 1000 ppm of CO_2 and potentially 50 per cent at 1400. Following the distribution of CO_2 monitors to English educational institutions, studies on levels of this gas have emerged. One in West Yorkshire found average classroom CO_2 at 959 ppm over an academic year, with 4846 hours recorded at above 1500 ppm.

For lag-free comms, try spooky action at a distance

Letters, 3 May

From Roger French,
Londonderry, New Hampshire, US

Martin Edwardes's letter, about "laggy" communications in space, got me thinking. Is anyone working on using instantaneous quantum entanglement for this? Mars can be up to 22 light minutes away – a disaster for real-time exchange.

Does this eerie glow help deep-ocean predators?

17 May, p 11

From Quentin Macilray,
Poole, Dorset, UK

Apparently all living things emit an eerie glow that is snuffed out upon death. Presumably this also applies to deep-sea creatures that otherwise live in total darkness. The question is, can this faint light be perceived by predators at that depth, to help them find prey? ▮

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THE WORLD INSIDE YOUR HEAD

IMAGINATION allows us to detach ourselves from the here and now and sends us crashing into the past, the future or entirely fictional realms. Some have even argued it is our most distinctive human capacity, a key element of our extraordinary success — and our most poignant failures, too.

In the past few years, we have really got to grips with the nature of imagination, from the neural networks that conjure it to the fascinating variations in the way people experience it. Recent insights from neuroscience and psychology have transformed it from a mysterious and intangible concept to an observable, neurologically distinct process. Researchers have begun to uncover the brain architecture underlying imagination and see it at work in real time. They have discovered that some people have a hypersensitive imagination, while others have none whatsoever, and have revealed many ways of boosting our imaginations to better our lives.

Over the next 10 pages, find out how your brain conjures your imagination and how it changes as you age. Discover what your own imagination really looks like and how it differs from other people's. And learn how to harness your imagination to learn a new skill and achieve your goals. Used correctly, a bit of imagination might be all you need to be happier and healthier.

BRETT RYDER

WHERE DOES IMAGINATION COME FROM?

By Caroline Williams

Understanding what happens in your brain when it produces your inner world can help you boost your imagination

UNLIKE more specialised kinds of mental processing, there is no dedicated "imagination cortex" that shows up on brain scans. Instead, imagination is the result of inputs from all corners of the brain and throughout the body.

We know that imagination doesn't come in just one variety (see "Inside the different types of imagination", page 35) and isn't experienced the same by all of us (see "What our differing imaginations tell us about the brain", page 36). But in recent years, neuroscientists have begun to get a clearer understanding of how the components of imagination work in the brain.

Advances in scanning the active brain – specifically, functional magnetic resonance imaging (fMRI) – have revealed that it is organised into several key networks. Each shares information within its network while also keeping in touch with others. This allows the brain to switch between different "modes" of thinking by selecting the right network for the job at hand.

There are three key networks involved in our imaginations. The one most associated with such thought was discovered by accident in the late 1990s, when neuroscientists noticed a distinct pattern of brain activity when research participants were left waiting in fMRI scanners between tasks.

Regions of the brain associated with memory, mood and self-reflection became more active when the participants weren't occupied by a particular task, signalling an internally focused state of mind. This became known as the default mode network (DMN), and it is in play when we let our minds wander, mull over memories, think about the future or daydream.

However, the DMN isn't the only network now known to be involved in what we think of as imagination. If the DMN's musings are to reach conscious awareness, the brain also needs to loop in the salience network. This connects regions involved in emotion, attention and motivation, acting as a project manager, sifting through external stimuli and internal noise to determine what is significant. In terms of imagination, it is there to flag up ideas and memories that are too important, surprising or urgent to ignore.

The salience network is also where inputs from the body affect imagination. The network is anchored in the insula, a part of the brain that processes bodily sensations that can be related to emotional states. When these sensations are triggered by our imagination or a memory, for example, the recollection of a frightening experience causing your heart to race, it makes our musings feel more visceral.

Though the DMN and salience network can together create an experience of imagination – say, picturing the house you grew up in or the ideal combination of toppings on a pizza – as Evangelia Chrysikou, a creativity researcher at Drexel University in Pennsylvania, says: "Imagination doesn't equal creativity." For that, we need another network.

To get creative – in the neuroscientific sense of generating original ideas that serve a purpose in the real world – the brain needs to call on the central executive network. This links frontal areas to those further back in the parietal cortex, which help direct and sustain our attention so that we can hold a goal in mind while working through possible solutions.

Brain imaging studies by Chrysikou and others demonstrate that people who score better on tests of creativity have stronger connections between all three key imagination networks. This might allow them to rapidly switch back and forth between generating, noticing and evaluating ideas.

So how can we encourage these systems to work together and improve our imagination? For a start, we can encourage activity in the DMN by taking time to let our mind wander. We can also physically go for a wander: a study by researchers at Stanford University in California found that a short walk increased creative idea generation by 60 per cent in the moment and for a short time afterwards.

And once you are moving and imagining, try focusing your imagination on something that matters to you. The salience network makes sure that you notice changes related to the excitement of a sudden breakthrough.

This means that the more you care about coming up with a solution, the more likely you are to feel it when inspiration strikes and to find the motivation to act on it.

THE EVOLUTION OF OUR MIND'S EYE

The human imagination is a remarkable thing. It has given us the novels of Jane Austen, the songs of R.E.M. – and atom bombs. We can imagine alternative histories in which the second world war didn't happen, or daydream about a long-lost teenage crush. "All of these things emerge from this human capacity to think beyond the material, or the immediate sensory realm," says Agustín Fuentes, a biological anthropologist at Princeton University and author of *The Creative Spark: How imagination made humans exceptional*. "Where did this come from? Well, clearly, it evolved."

Non-human animals have some degree of imagination. Many can plan ahead: Portia jumping spiders can devise complex attacks on prey, for example. Our imagination is an elaborated version of this.

We can see the emergence of imagination in the fossil record of our hominin ancestors – especially in the stone tools they made. "To change the shape of a rock into a new form that's usable requires a kind of imagining that we just don't see evidence of in other organisms," says Fuentes.

The oldest known stone tools are 3.3 million years old, from Lomekwi in Kenya. That's before our species, or even our genus, *Homo*, evolved. Clearly, earlier hominins had enough imagination to make and use stone tools. Later, hominins started creating meaning, for instance by painting themselves and cave walls with red ochre, or engraving symbols.

The development of language was a "phase shift" that greatly enabled our imaginations, says Fuentes. "The way in which we have to convey, store and retrieve information opens the door to a lot of other things," he says. In particular, we can easily convey our ideas to each other – something even our closest relatives, chimpanzees, struggle to do.

The importance of language in imagination speaks to a wider point: "Imagining is actually incredibly social," says Fuentes. "We [often] talk about other people's imaginations, especially when we talk about artists or geniuses… Our imaginations are not our independent creations, but rather the amalgamations of all of our lived experiences and [the] experiences of so many other people."

Michael Marshall

ADBOBE STOCK/BRETT RYDER

HOW YOUR IMAGINATION CHANGES AS YOU AGE

By Michael Marshall

It is natural to associate wild flights of fantasy with children and a more mundane internal world with adult life. But that isn't the whole picture

AS CHILDREN grow into adulthood and then continue ageing, what happens to their imagination? Do all of us gradually lose our innate capacity to conjure up novelty amid the drudgery of life, or does experience teach us to fine-tune it? Paul Harris, a developmental psychologist at Harvard University, has argued that imagination gets better with age, stating in a 2021 review that young children's pretend play generally sticks to "everyday regularities"; only later do they start imagining dramatic counterfactuals. In particular, Harris points to an apparent shift around the age of 4, when children start to be able to imagine two mutually incompatible possible outcomes for an event.

This is supported by studies showing that children often fail creative tasks that adults pass. In one such test, participants are asked to retrieve a handled bucket. To do this, they are given a straight pipe cleaner. The solution is to bend it into a hook, but children younger than 5 rarely figure this out.

Angela Nyhout, a developmental psychologist at the University of Kent, UK, has been working on understanding how our imagination might shift with age. In as-yet-unpublished work, commissioned

by English Heritage, Nyhout and her colleagues asked visitors at Dover Castle, UK, how they might use various historical objects, including a mould in the shape of a warrior god and a dress fastener. "Older adults came up with more creative possibilities than younger adults," she says.

That tracks with the work of Andrew Shtulman, a cognitive developmental psychologist at Occidental College in Los Angeles, who argued in his 2023 book *Learning to Imagine* that imagination is a skill that we develop with practice.

The idea that imagination increases in line with the number of candles on your birthday cake isn't uniformly accepted, however. Alison Gopnik, a psychologist at the University of California, Berkeley, has conducted research indicating that children are more open-minded than adults. This is because they know less about the world, says Nyhout: "They don't really have a very strong expectation [of what might happen], so they're more likely to explore a number of different spaces."

What does seem to be true is that our imagination evolves. Nyhout's team has experimented by asking children in different age brackets how problems from stories could be resolved. In one, a child sits on his front porch drawing, then goes inside to get some juice – only for the wind to blow his drawings away. While older children often say the boy should have brought his drawings inside, preschoolers sometimes come up with out-of-left-field – and more imaginative – ideas like "the wind shouldn't have blown".

ALAMY/BRETT RYDER

What's more, in her study at Dover Castle, she found that "young adults and adolescents seem to be a bit more flexible in their thinking", says Nyhout. While older adults envisioned more ways that an object could be used, they generally stuck to the same domain, such as "kitchen", whereas younger adults roamed more widely.

Nothing exemplifies these contradictions more than studies of people's mental imagery. There is evidence that our visual imagery becomes less vivid as we get older. However, this seems to reflect changes in what we prioritise when we imagine things. "Typical older adults are less likely to zoom in and remember the very specific details that make up a past event," says Jessica Andrews-Hanna, a cognitive scientist at the University of Arizona. Instead, they focus on "the overall gist of the memories", she says, especially their meaning and significance.

Viewed negatively, "our memories, our ability to remember the details, fade as we get older", says Andrews-Hanna. However, "maybe that's not a bad thing". Instead of fixating on details, "we may want to access our experiences at the level of meaning", she says.

"I think it's clear that our imaginations have different features at different ages," says Nyhout – but that doesn't mean it gets better or worse. "The child's imagination might be optimal in some settings and inadequate in others, and vice versa," she says. "Because of these differences, collaboration across ages might help us to come up with solutions to pressing problems, like reducing inequality or sustainable development."

"THE CHILD'S IMAGINATION MIGHT BE OPTIMAL IN SOME SETTINGS AND INADEQUATE IN OTHERS"

INSIDE THE DIFFERENT TYPES OF IMAGINATION

By Adam Zeman

Imagination isn't just one thing – it turns out there are at least four forms

LIDYA NADA/UNSPLASH

1. REPRODUCTIVE IMAGINATION

Conjure up the image of an apple in your mind's eye. Is it green or red? Does its skin shine? Does it have a stalk? Can you get a sense of its weight as you gently twirl it? Does it have a scent? If these questions make sense to you, you have created a "sensory image" of an apple. This kind of imagination is known as reproductive. You know an apple's properties, so you can reproduce apple-like sensations in the absence of the real thing. (Those who are born blind don't have the visual element of this sort of imagination, but can, of course, imagine movement, a sense of space, smells, sounds and so on).

Research suggests that when you do so, the brain regions that activate strongly when you look at an apple activate weakly, giving your imagery its visual feel. We know this because brain imaging has shown directly that visual cortices fire up when we visualise things. Plus, forming an image can have similar physiological effects to looking at the real thing. For example, if you imagine looking into the sun, your pupils will constrict.

2. CREATIVE IMAGINATION

Once we can create images of things in their absence, there is plenty of scope for tinkering with them. When we do this, we nudge our reproductive imagination into the productive, also called the creative, kind. We harness this style of imagination in both humdrum contexts ("How will my friend feel if I touch on that difficult subject?") and innovative ones, such as when a playwright creates a startling denouement or a physicist posits a new fundamental particle.

Imagery seems to be a frequent ingredient in the process of creation – but not an essential one. If someone with aphantasia, who lacks a visual mind's eye, is asked to imagine an apple behind their eyelids, nothing appears (read more on this in "What our differing imaginations tell us about the brain", page 36). Yet such individuals can also be creative, producing things that are new and useful, from the latest tech to pieces of music.

3. PERCEPTIVE IMAGINATION

The two kinds of imagination mentioned previously are arguably the offspring of a more fundamental form, which allows us to experience the world around us. We don't usually consider our day-to-day perception of everything we see – the books on our bedside table, our toothbrushes in the bathroom, the sky as we step out of our front door – as "imaginative", but the latest research indicates there are strong reasons for deeming it so.

Our waking experience depends on our hard-won knowledge of the sensory world – from painstakingly learning to hear, see, smell and experience touch – in collaboration with our brain's ceaseless activity.

Take colour, for instance. We experience leaves as being green, but "green-ness" isn't an objective property of a leaf, the way that, say, its mass is. Instead, the way the leaf reflects the light that hits our eyes when we look at it produces what we collectively call "green". As such, the stance taken by leading neuroscientists, including Anil Seth at the University of Sussex, UK, is that our experience is a controlled hallucination. "We perceive the world not as it is, but as it is useful to us," Seth writes in his book *Being You: A new science of consciousness*. This, too, is a type of imagination in action.

4. CULTURAL IMAGINATION

We now come to concealed, or cultural, imagination. We are deeply cultural creatures, shaped by our heritage during our individual lives and adapted to culture by our evolutionary history. Our cultural heritage, from the style of clothes we wear to the tools we use to prepare food and the sort of homes we live in, is the cumulative creative product of human imagination, but its imaginative origins are often invisible to us.

As you might intuit, cultural imagination is often culturally specific. A British person's cultural imagination is likely to be different from a Japanese person's. Deep-seated beliefs, like faith in a particular deity or that a specific way of running society is optimal, are the products of imagination.

So, too, are deeply damaging ideas, such as that one race is superior to others. Such cultural beliefs are sometimes mistaken for objective facts.

The science of imagination can surely contribute something here to social good. As cultural creatures, we should respect traditions – they make us who we are – while acknowledging that they are human creations, sometimes wonderful, but still fallible and malleable, with the capacity to result in both extraordinary good and tremendous harm.

GETTY/BRETT RYDER

WHAT OUR DIFFERING IMAGINATIONS TELL US ABOUT THE BRAIN

By Adam Zeman

One mind can create a very different reality to another. What does this tell us about how we make sense of the world?

BECAUSE we live our lives entirely in our own heads, understanding the contents of someone else's – and how radically their experience might differ from our own – is hard. New research, though, is revealing just how diverse the human imagination can be.

Take the concept of a "mind's eye". You might take being able to conjure up mental images in your imagination as a given. But research from myself and others has shown that 1 to 4 per cent of the population have aphantasia, meaning they lack wakeful visual imagery – ask them to "see" a hippo floating down a river on a pink lilo, and nothing happens. (Most people with aphantasia experience visual imagery in their dreams, however.)

Aphantasia is often associated with a "thinner" than usual memory for personal past or autobiographical events, and sometimes with autism and difficulties with face recognition. People with aphantasia are more likely than those with exceptionally vivid imagery to work in STEM areas. They often report that close relatives are also aphantasic, hinting at a genetic basis. Aphantasia may be protective in some ways, possibly offering some defence against medical conditions involving imagery, like post-traumatic stress disorder (PTSD).

Fully understanding the brain signatures of aphantasia is a work in progress, but five papers published this year and last have begun to help us untangle what is going on. One brain-imaging study, for example, has shown how the regions associated with visual imagery do fire in those with aphantasia, but slightly differently, with less connectivity between the parts that deal with thought and vision.

Hyperphantasia, the converse of aphantasia, is estimated to affect 10 per cent of people. Here, imagined imagery is "as vivid as real seeing", with those affected often reporting a rich autobiographical memory. The mind's eye is so intense in people with hyperphantasia that they can confuse real events with imagined ones. Such vivid imagery seems to nudge them in the direction of traditionally "creative" careers, such as designing and film-making, and may place them at greater risk of conditions fuelled by imagery, like PTSD.

Research also shows that they may be more likely to experience maladaptive daydreaming, spending countless hours lost in fantasy, with dire consequences for their real-world lives, though further studies are needed to clarify these links. Brain-imaging studies demonstrate that, when they imagine, people with such detailed imaginations have enhanced connectivity between the regions associated with thought and vision.

Imaginations can also be affected by neurological and psychiatric conditions. Epilepsy, in which abnormally synchronised neuronal discharges march around the brain, can trigger sensory hallucinations, for example – such as the sensation of an overpowering smell – and experiences of reliving, from déjà vu to full-blown recollection. Parkinson's disease, which affects both early visual processes in the brain and their subsequent interpretation, is associated with visual disturbances including pareidolia – the tendency to spot familiar objects where we know none exists – and hallucinations, often of animals and people who may cohabit peacefully with the affected individual.

IMAGINATION UNLEASHED

Hearing voices is another case of imagination slipping off its leash. Healthy voice-hearing – the type that isn't associated with any psychiatric condition – is estimated to occur regularly in around 1 per cent of the population. In another 1 per cent, however, it is a symptom of psychosis, in which people become persuaded of the reality of their hallucinations and of the truth of delusions, defined as bizarre false beliefs that aren't shared by others, like that we are "the left foot of God" or the victims of a global conspiracy.

Voice-hearing has sometimes been traced to "misattribution" of inner speech – if the background inner commentary that many of us describe becomes projected into the outer world and experienced as if it were autonomous. What can we learn about the brain from these dramatic disturbances? They remind us that our experience isn't delivered to us directly by the world but is the outcome of complex brain processes.

If our normal awareness can be understood as a "controlled hallucination" in the sense that all our experience is "generated" by the brain, then our experience of the real world is a hallucination that corresponds – more or less – with reality.

If this is true, we should expect, at times, to be challenged by the distinction between the real world and fantasy.

CAN AN AI IMAGINE?

When you watch an artificial intelligence model write passable poetry or conjure up images from text prompts, it is easy to ascribe human-like imagination to the computer program. But is that what's happening, or is it merely a stochastic parrot regurgitating training data?

Iyad Rahwan at the Max Planck Institute for Human Development in Germany has spent a career trying to understand AI not just from a technical point of view, but also as a social and behavioural phenomenon. He believes there are two styles of imagination relevant here. One is combining concepts, like when an AI draws a chair in the shape of an avocado on demand. The other is understanding the consequences of actions and being able to develop plans. (Both fit under the "productive/creative imagination" bracket – see "Inside the different types of imagination", page 35.) We know AI is capable of combining concepts, says Rahwan. And ask a large language model complex questions and you realise that it has at least some understanding of cause and effect.

"If you think of it at this kind of mechanistic level, then you could say that machines can totally replicate this process," he says. "They do very good analogical reasoning." For Rahwan, there is nothing inherently lacking in an AI model that prevents it from having an imagination, unlike consciousness or self-awareness – traits that AI doesn't yet possess and, arguably, cannot, depending on how you think about such concepts.

But while AI can certainly imagine, it may be incapable of the precise sort of imagination we have, which is a product of our bodies, senses and experience of the world. AI may lack our embodied understanding of our surroundings, but, on the other hand, it has direct access to mountains of data, instant worldwide communications and vast processing power, which we don't. As such, AI imagination is likely to vary in ways that are hard for us to comprehend.

Just as AI has beaten the world's best human players at chess and Go by inventing counterintuitive moves and tactics, it may look at battlefield strategies, drug design or nuclear fusion with similarly fresh and capable eyes. "It's able to then, perhaps, create strategies that are alien to us," says Rahwan. "I can imagine that, in principle, they may even have superior imagination to us in certain domains."

But – for the moment, at least – Rahwan isn't convinced that AI can imagine truly groundbreaking concepts like those dreamed up by our most revered human geniuses. "Could machines that we have today, had they been trained on knowledge up to 1900, imagine general relativity?" asks Rahwan. "I don't think so. But this is a very rare ability in humans too."

Matthew Sparkes

> ***"AI MAY LOOK AT DRUG DESIGN OR NUCLEAR FUSION WITH FRESH AND CAPABLE EYES"***

HOW VIVID IS YOUR MIND'S EYE?

By Adam Zeman

Reckon you are highly imaginative? Or fear you are lacking in the creativity department? Put your presumptions to the test, with these challenges

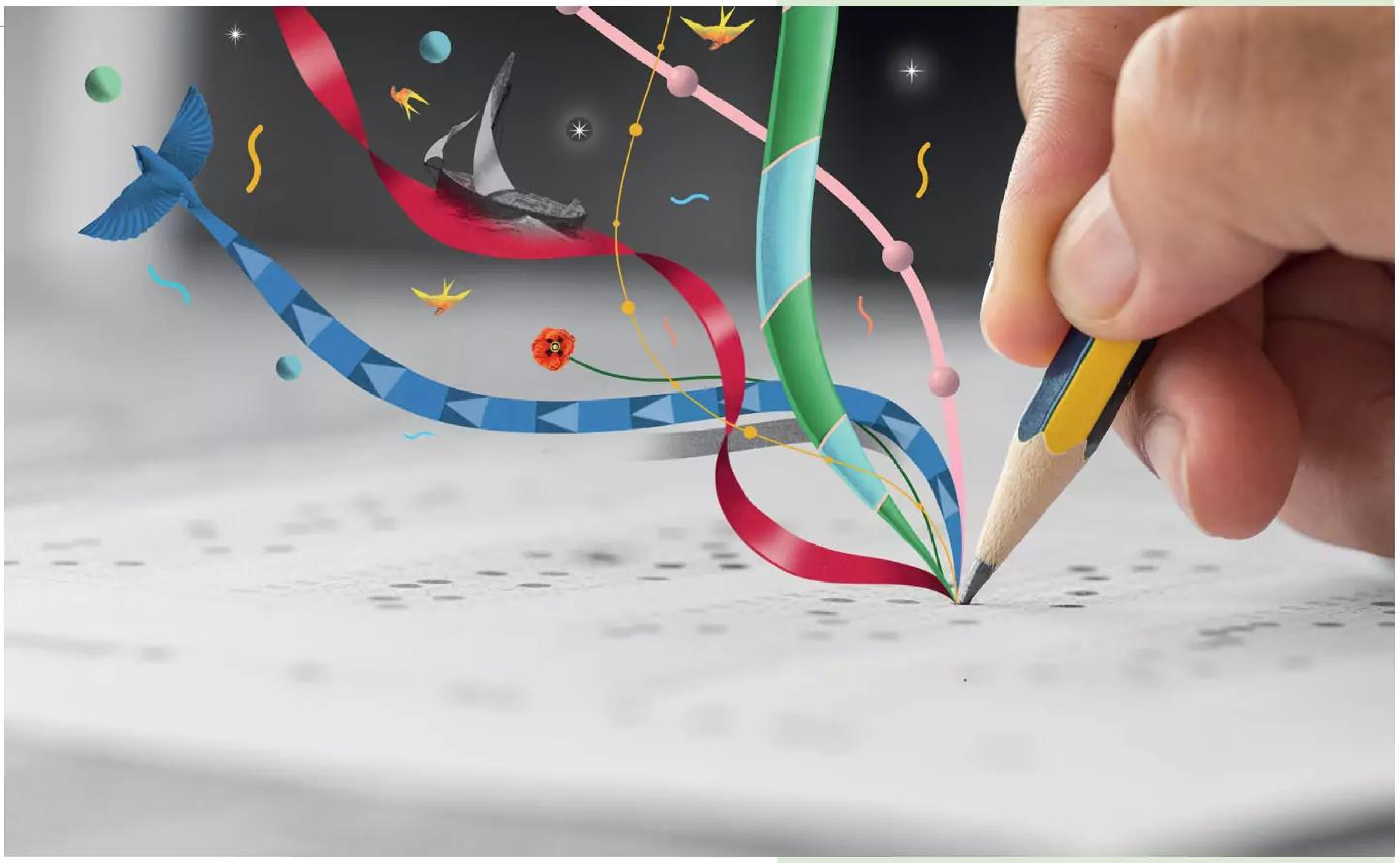
The type and vividness of imagination we have varies greatly (see "What our differing imaginations tell us about the brain", left). As it exists in several forms, no single test can measure it – but here is a handful of ways to gauge the resources of your own imagination.

TEST 1

The strength of reproductive imagination – our ability to visualise the appearance of things in their absence, hear their sound or recreate their tactile feel – has typically been assessed using vividness surveys. Here are four scenarios adapted from the Vividness of Visual Imagery Questionnaire.

Visualise a rising sun. Carefully consider the picture that comes before your mind's eye:

1. When the sun rises above the horizon into a hazy sky
2. When the sky clears and surrounds the sun with blueness
3. When clouds appear and a storm blows up with flashes of lightning
4. When a rainbow appears


ADOBE STOCK/BRETT RYDER

Then rate each of the four images you formed, if any, on the following scale:

Perfectly clear and as vivid as real life = 5
Clear and reasonably vivid = 4
Moderately clear and lively = 3
Vague and dim = 2
No image at all, you only "know" that you are thinking of the object = 1

A score of 4/20 would raise the possibility of aphantasia, the inability to visualise mental images. A score of 20 might point to hyperphantasia, the ability to "see" incredibly vivid mental imagery, often as detailed as actual vision.

Most of us will score in the low to mid-teens for these four examples (the full test has 16 such scenarios, with a score range from 16 to 80).

TEST 2

Here are some questions tapping into other aspects of our senses from the Plymouth Sensory Imagery Questionnaire:

IMAGINE:
The sound of children playing
The smell of a rose
The taste of a lemon
Touching a soft towel

Rate the vividness of your image on a scale from 1 to 10, where 0 is "no image at all" and 10 is as clear and vivid as real life.

People score 6 to 7 on each of these images, on average.

The vividness of imagery in one sense aspect typically correlates with vividness in others, but there are exceptions: people who lack a mind's eye sometimes have an active mind's ear, for example.

TEST 3

Creative or productive imagination, the ability to come up with novel solutions to problems – novel to you, at least – can be tested with either open-ended tasks that have a large set of solutions or convergent tasks that have a single solution. In real life, your capacity to make things that are both new and useful, the standard definition of creativity, seems to depend on a happy combination of well-developed skill and playful spontaneity.

Here is an open-ended task: How many uses can you think of, in 2 minutes, for a brick?

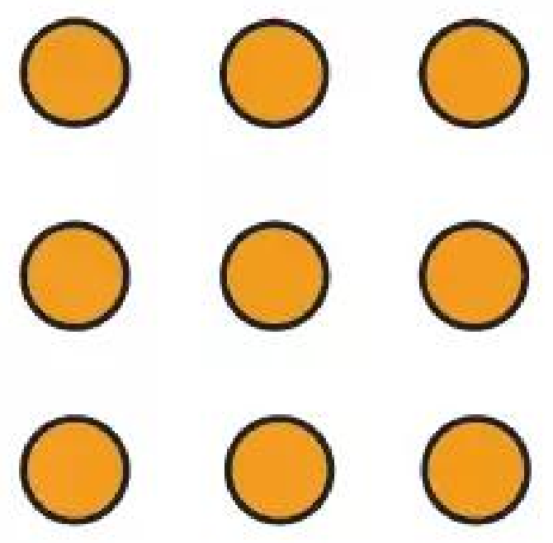
Answers can be scored on variables including fluency (the number of uses) and flexibility (the number of categories of use).

The average number of uses thought of is nine. The average number of categories thought of is four.

TEST 4

The next is a visuospatial task:

Without lifting your pencil from the paper, use four straight lines to connect all nine dots in the grid below



TEST 5

The final test comprises two examples of a verbal task from the Remote Associates Test:

What single word relates the three that follow:
Pine, tree, sauce
Room, blood, salts

Tests 4 and 5 can be solved either by racking your brain or, if you are creative and lucky, by a moment of illumination. The Remote Associates Test, for example, has been used to study the brain activity linked to sudden insight. Don't get disheartened if inspiration deserts you on this occasion – but be very proud if you came up with the answers, which are found on page 41.

DAYDREAM YOUR WAY TO NEW IDEAS

The uses of imagination aren't limited to controlled visualisation (see " How to harness the power of your inner world", right). We can also benefit from directionless daydreaming, when we allow our thoughts to wander from idea to idea. Evidence suggests that daydreaming can be especially important for creativity, allowing the brain freedom to form connections between disparate elements and, hopefully, to come up with something original.

Those light-bulb moments don't appear out of nowhere, however. In general, you need to have done some preparation first, researching the area or consciously brainstorming a few initial ideas. Then you need to allow some time for the information to "incubate", setting aside whatever you are working on and not consciously thinking about it.

Go for a stroll, take a shower or even a nap, and allow your brain to relax the constraints on its thinking. And, as you daydream during or after these activities, you may find that an ingenious new idea floats into your mind of its own accord.

David Robson

HOW TO HARNESS THE POWER OF YOUR INNER WORLD

By David Robson

Sharpening your imagination is the secret tool of top athletes and business people. Here's how you can develop yours

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FEELING stressed about an upcoming event? Imagine, for a moment, that you have a magic anti-anxiety pill in front of you that will take away your nerves. Picture its packaging, and feel yourself popping the pill from its foil. Now, visualise bringing it to your mouth, dropping it in, and conjure up the sensation of swallowing it.

These were the instructions that Jens Gaab and his colleagues at the University of Basel in Switzerland gave participants in a recent study investigating the possibilities of the placebo effect. The participants, university students who were studying for an exam, were instructed to repeat the procedure twice a day for three weeks.

Remarkably, it worked — those who took an imaginary pill experienced less test anxiety than control participants who were simply asked to report their anxiety levels as the exam approached. "And their performance was significantly better," says Gaab.

It is now well accepted that placebo pills can sometimes relieve symptoms, and the results from Gaab and his team suggest we can achieve the same effect when that pill exists only in our mind. It is just one of many surprising ways that imagination may help to improve our health, happiness and success. So, what can we do to make the most of these benefits?

The power of visualisation is well known in sports science. "Multisensory imagery is a game changer when it comes to performance," says Jonathan Rhodes at the University of Plymouth, UK. "If you can rehearse all the challenges that you might come up against, you'll be better prepared in the moment."

When imagining a movement, we often activate the same areas of the brain associated with its execution. These mental rehearsals or simulations help refine the neural pathways we use to perform the task for real, and so can improve our performance.

For instance, researchers at Manchester Metropolitan University and the University of Chester, both in the UK, asked one group of skilled golfers to mentally rehearse bunker shots twice a week for six weeks. A second group was told to practise on a real course, while a third was asked to use both kinds of practice. Both the mental and the physical practice groups improved more than a control group who didn't practise at all – but the greatest gains were made by those who combined the two.

Mental rehearsal has been shown to offer similar benefits for gymnasts and basketball players, while a 2020 review of the evidence found that performance improved across different skill levels and settings. And it isn't just athletes who can reap these rewards: research shows that musicians can enhance their speed and timing accuracy with mental practice.

"There's now a lot of evidence," says Francesco Pagnini at the Catholic University of the Sacred Heart in Milan, Italy. "I think that a lot of the techniques that come from the sports side will definitely be helpful in health as well."

Pagnini points to a recent study by Kaya Peerdeman at the University of Leiden in the Netherlands and her colleagues: participants were asked to hold their hands in a bucket of icy water, first without any guidance on what to think and then later imagining that they were wearing a warm, waterproof glove.

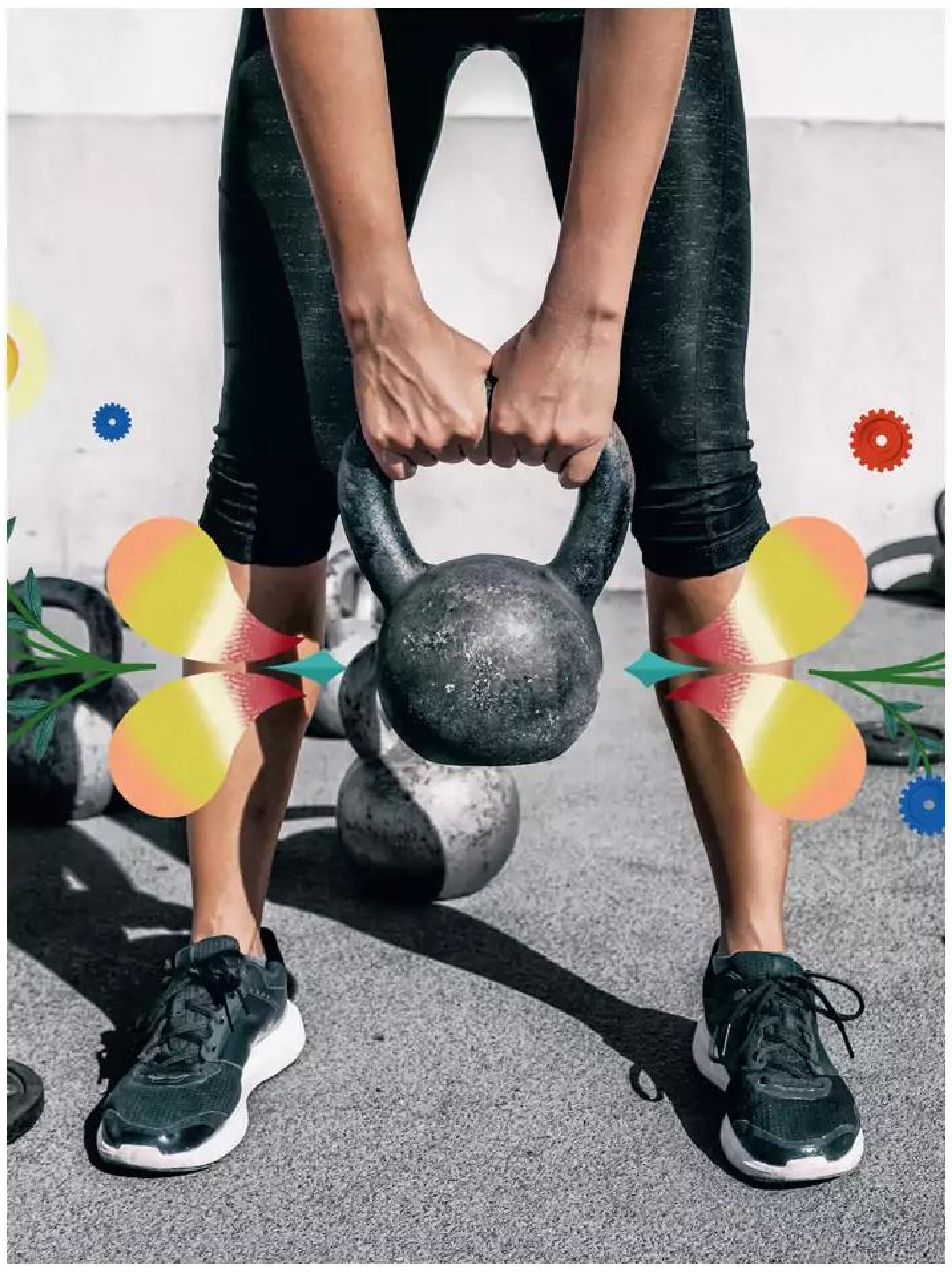
Peerdeman found that when participants imagined wearing a glove, they reported a reduction in their pain. Findings like these could have clinical applications. Other studies have suggested that guided imagery can reduce the pain experienced by people going through uncomfortable medical procedures or recovering from operations.

If you struggle to conjure up mental imagery or scenarios (see "How vivid is your mind's eye?", page 37), don't worry – Rhodes's research suggests we can all develop these skills. In 2023, he tested the multisensory imagination of 329 athletes, selecting the 27 with the lowest scores. Half of these athletes were given "functional imagery training", while the rest were put on a waiting list. The training included individual coaching that expanded on whatever vague images and sensations the participants could already imagine. For example, they might be presented with photos or sounds that would help to place them in the necessary scenario and then encouraged to elaborate.

VIVID EXPERIMENTATION

Sure enough, the first group developed more vivid imaginations compared with the controls on the waiting list, who also improved once they were allowed to take part in the training. Importantly, the effects lasted for six months after the training ended. "Some people react really quickly, and love it," says Rhodes.

Rhodes emphasises that improving your imagination is an incremental process. He recommends starting with a sense that is relatively easy to imagine and slowly adding more details as your confidence builds. "Play around," he says. "Be an experimenter."



ADOBE STOCK/BRETT RYDER

CAN IMAGINING A BETTER FUTURE REALLY MAKE IT COME TRUE?

By Helen Thomson

Manifestation is easy to dismiss as unscientific nonsense, but neuroscientist **Sabina Brennan** believes there are aspects we could all benefit from

FIRST popularised by the bestselling New Age book *The Secret*, manifestation has remained a cultural phenomenon for decades, championed by people from Oprah Winfrey to Deepak Chopra. Advocates claim you can attract whatever you want – whether that's a romantic partner, a new business opportunity or even a material object – by asking the universe for it and believing that it can deliver. Some practitioners propose physics-defying explanations that evoke mysterious vibrational forces to explain its effectiveness.

This is clearly nonsense, but neuroscientist Sabina Brennan was nevertheless intrigued. What might be the real reason that the practices involved in manifesting can benefit people's lives? She realised that there were several fascinating, evidence-based explanations for why such interventions can rewire the brain in ways that help you achieve what you desire. In her new book, *The Neuroscience of Manifesting*, Brennan unpacks some of the mechanisms behind this enduring practice.

Helen Thomson: Can you start by telling me what manifestation is?

Sabina Brennan: Manifesting is the practice of transforming thought into reality by visualising your goal and then developing the discipline to stay focused on and take action to achieve that goal. You can't magically make things happen – you can't defy physics – but you can change your reality and your future through focused action.

Manifestation is easy to disregard as unscientific nonsense – why did you think differently?

There are a few reasons why manifesting is dismissed by some academics. One is the misconception that manifesting is just wishful thinking rather than the focused discipline of taking action to attain goals. Another relates to the fact that some people who earn a living from helping people manifest their futures invoke quantum mechanics to explain manifesting. This has led some leading scientists to label it as quackery.

Some [manifesting advocates] propose that our thoughts and feelings transmit powerful messages that are received by the universe or some higher power, who then sends back life experiences to match the original thoughts and emotions. That's obviously not scientifically accurate. Another reason manifesting is dismissed is its associations with magic and mysticism.

I am concerned for vulnerable people who may pay hundreds of pounds to "manifestation coaches" [who teach them to buy into such beliefs]. But there's absolutely no need to invoke any of those explanations – there is existing science that adequately explains what's happening. For instance, it was clear to me that there were several parallels between manifestation and components of CBT [cognitive behavioural therapy].

Can you tell me more about that aspect?

CBT is a well-researched, scientifically grounded psychotherapeutic treatment that helps individuals understand the thoughts and feelings that influence their behaviours. Similarly, manifesting holds that by consciously directing our thoughts and emotions, we can influence our actions and, consequently, the events in our lives. Manifestation works, just not for the reasons that many people think.

OK, let's start with what you describe in your book as manifestation's first step: self-compassion. Why might that help us achieve our goals?

It's hard to silence that voice in your head that constantly criticises you, but there's evidence to back up the benefits of being kinder to ourselves. When we use imaging tools to look at the brain while people are thinking self-compassionate thoughts, we see reduced activity in the amygdala, a brain region involved in fear and stress, which suggests that self-compassion may help soothe these states.

We also know that if you practise loving-kindness meditation, which is related to self-compassion, it lowers stress and emotional responses. Uncontrolled stress can hinder learning, harm memory and adversely affect your brain's structure and function. This all makes it more likely that we fall into unhelpful behaviours and habits that may prevent us from attaining our goals.

Part of manifestation is regularly thinking about what you want from your future, such as by making a vision board, a collage of words and pictures illustrating your goals. How does this help?

I believe this has to do with overcoming your brain's cognitive biases. It's to do with a theory called predictive processing.

You might think that everybody sees an objective reality, but neuroscientists know that's not true (see "Inside the different types of imagination", page 35). The brain is constantly bombarded with billions of bits of data from your senses and predictive processing theory suggests that, in order to create your perception of the world, your brain needs to filter the important bits and combine that information with your past experiences, your biases, your ideas of the world. The brain uses predictions and best guesses to build our perception of an external world that it doesn't directly experience.

To filter the relevant data, your brain first focuses on information key to your safety and survival. It also filters unusual or unexpected data. Then it will filter whatever is relevant personally to you. Take this example: just before I got married, our car caught on fire and my partner suggested we buy a Mazda 323. Suddenly, I'm seeing them everywhere. It wasn't that I attracted them to my life. They were always there, they just weren't relevant to me.

ALAMY/BRETT RYDER

> **"MANIFESTATION WORKS, JUST NOT FOR THE REASONS THAT MANY PEOPLE THINK"**

Understanding predictive processing helps you to understand why this step of manifesting works. Having clarity of vision supports focused attention, activating the [brain's] salience network, filtering in information and new opportunities that are relevant to you achieving your goals.

So, manifesting unlocks a new perception of reality?
Yes. We couldn't survive if our brain didn't take shortcuts. But that means we tend to see and do the same things all the time. When you make a vision board, you're changing the message to your brain – saying, "This is what I want to see" – so that your brain is tagging that as salient information. [Because of how our brain filters information,] it is possible for us to completely miss opportunities that are right in front of us.

Manifesting sounds more difficult than I thought!
Manifesting harnesses neuroplasticity, our brain's capacity to adapt to change in the world. But this requires conscious effort and action, which is hard. Our brains favour the status quo, their primary function being to keep us alive, and with change comes uncertainty and risk. We also have a natural tendency to resist change because it's more effortful than engaging in habitual, routine behaviour.

Can you give our readers some things they can do to best harness the power of manifestation without going down the magical thinking line?
Each time you catch yourself in a self-critical thought, take a moment and make a conscious effort to reframe it as if you were speaking to a much-loved friend. Over time, this gradually rewires the brain to choose self-kindness over self-criticism.

Self-awareness is also foundational. Try answering these questions every evening for a week: "What did I enjoy today?", "When did I feel most like myself?" and "What thought today might no longer serve me?"

Manifesting is fundamentally about change, so choose one small, new behaviour that supports your goal and commit to practising it daily for a week. This helps overcome the brain's resistance to change and reinforces action-driven transformation through consistency and novelty.

Gain clarity by starting each week by identifying actions you need to take and check in with this reminder each day. This sharpens the brain's salience network, and ticking off things you've achieved at the end of the day gives you a dopamine hit, keeping momentum going.

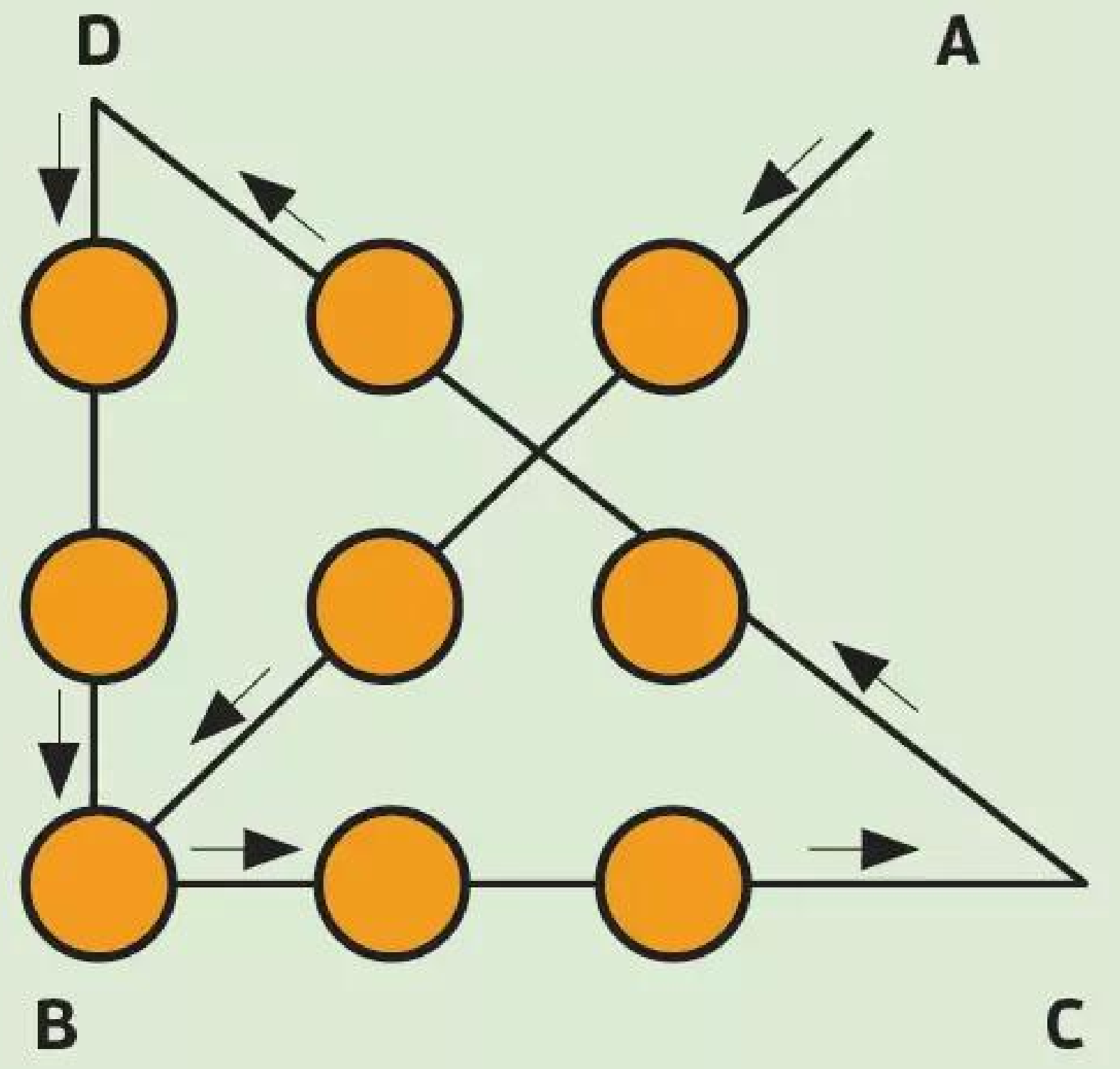
Coherence is vital. Each evening, quickly review your day by considering whether your actions reflected your long-term goal and what adjustments you might make the following day.

Finally, you need to "create" your best life using scientifically grounded techniques. Each morning, do a 5-minute practice that involves one affirmation, such as "I have what it takes, I've put in the work"; one sentence of gratitude ("I'm grateful for my health"); and one tiny reminder to act "as if" you're living the way you want to, like: "stand confidently".

This routine strengthens self-belief, rewires neural pathways through repeated positive reinforcement and helps you live into your desired reality each day. ▮

Answers to tests 4 and 5 on page 39

VERBAL TASK: Apple and bath
DOT TASK: See diagram below, starting your pencil at point A



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Delilah Gates,
Postdoctoral fellow,
Center for
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Debunking gardening myths

Feeling companionable

Will your tomatoes' yield and flavour be improved by growing tasty herbs alongside them? **James Wong** unearths the science

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, in London, he shares his tiny flat with more than 500 houseplants. You can follow him on X and Instagram @botanygeek

AS AN obsessive plant collector with little impulse control, I will take any excuse to cram a few more species into my tiny plot. So the concept of companion planting, an old belief that adding certain plants around existing crops can boost pest resistance, yields and even flavour, is one that has always appealed to me. But as a sceptical scientist, I'm curious about how well these claims actually stack up. Let's dive in.

The tricky thing with examining the science around companion planting is quite how many benefits it is said to have, so I'm tackling only the most common claim here: that tomato yield and flavour is improved by being grown alongside aromatic herbs, like the basil pictured here.

SHUTTERSTOCK/IRINA WS

I managed to dig up seven papers that set out to test this hypothesis, all of which had pretty consistent findings. The presence of aromatic herbs like marigolds, for example, seems to notably cut infestations of two of the most dreaded pests to afflict tomatoes: nematodes and whitefly.

This isn't entirely surprising. The ability of marigolds to defend themselves against predation by producing volatile compounds with pest-repellent properties, such as limonene (the molecule that gives lemon zest its scent), has been documented. The fact that trials have shown similar effects from other limonene-producing herbs, like some basil, but not from non-aromatic plants, like mustard, could be seen as further support for this idea.

What is surprising is that this apparent protective effect against pests didn't always translate into higher yields. While some studies have found a boost in yield of up to 59 per cent when growing tomatoes with herbs, growing them next to peppermint could create a 6.7 per cent drop in yield.

Researchers attributed this outcome to the herbs competing with the tomatoes for nutrients, light and water, which offsets any reduction in pest damage. (Anyone who has ever grown peppermint will be familiar with its megalomaniacal tendency to swamp all before it.)

But what about flavour? Comparatively fewer trials have investigated this aspect, but the results from those that have are pretty disheartening. The three studies I could find reported no appreciable difference in flavour – neither in objective, quantitative measures like sugar or acidity levels, nor in subjective measures like taste-test scores.

The bottom line: adding a range of fragrant herbs is indeed likely to reduce your tomatoes' risk of succumbing to pests. And, as long as you don't pick super vigorous ones like mint, they may also lift yields. While it doesn't seem to result in any real flavour boost in the tomatoes themselves, you'll also have loads of herbs to serve with them. What these companion plants may not do in your plot, they will certainly do on your plate. ■

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Debunking gardening myths appears monthly

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Soil: The hidden engine of life

We walk on it, grow our food in it, and rarely give it a second thought. But soil, says Andy Neal of Rothamsted Research, is far more than just dirt—it's a living, breathing system shaped by biology, physics, and time.

Neal's work reframes soil as an "extended composite phenotype"—a concept borrowed from evolutionary biology. Just as a bird's nest reflects the genetics of its builder, soil structure reflects the collective activity of microbial communities. These microbes, fuelled by organic carbon, create intricate pore networks that regulate oxygen, water, and nutrient flow—conditions that, in turn, shape which genes thrive.

But modern agriculture has disrupted this delicate balance. "We've starved the soil," Neal explains. "By depriving soil of organic matter inputs and ploughing annually, we've degraded its structure." The result? Poor water retention, and a reliance on costly fertilisers that often leach away or are lost as increased greenhouse gas emissions before plants can use them.

To tackle this, Neal's team is turning to AI. With thousands of microbial species and genes interacting in complex, microscopic networks, traditional analysis falls short. AI helps uncover hidden patterns, linking soil structure to microbial function and carbon cycling.

Crucially, this research isn't confined to the lab. Neal collaborates directly with regenerative farmers experimenting with composts and cover crops. "They're the real innovators," he says. "We bring the science; they bring the practice."

As climate change intensifies and food security becomes ever more pressing, understanding soil's hidden dynamics could be key. "Soil holds more carbon than the atmosphere and all plant life combined," Neal notes. "If we get it right, it's not just about better farming—it's about planetary health."

You can find out more by visiting the Future of Food and Agriculture stand at New Scientist Live 2025. For more details go to: live.newscientist.com

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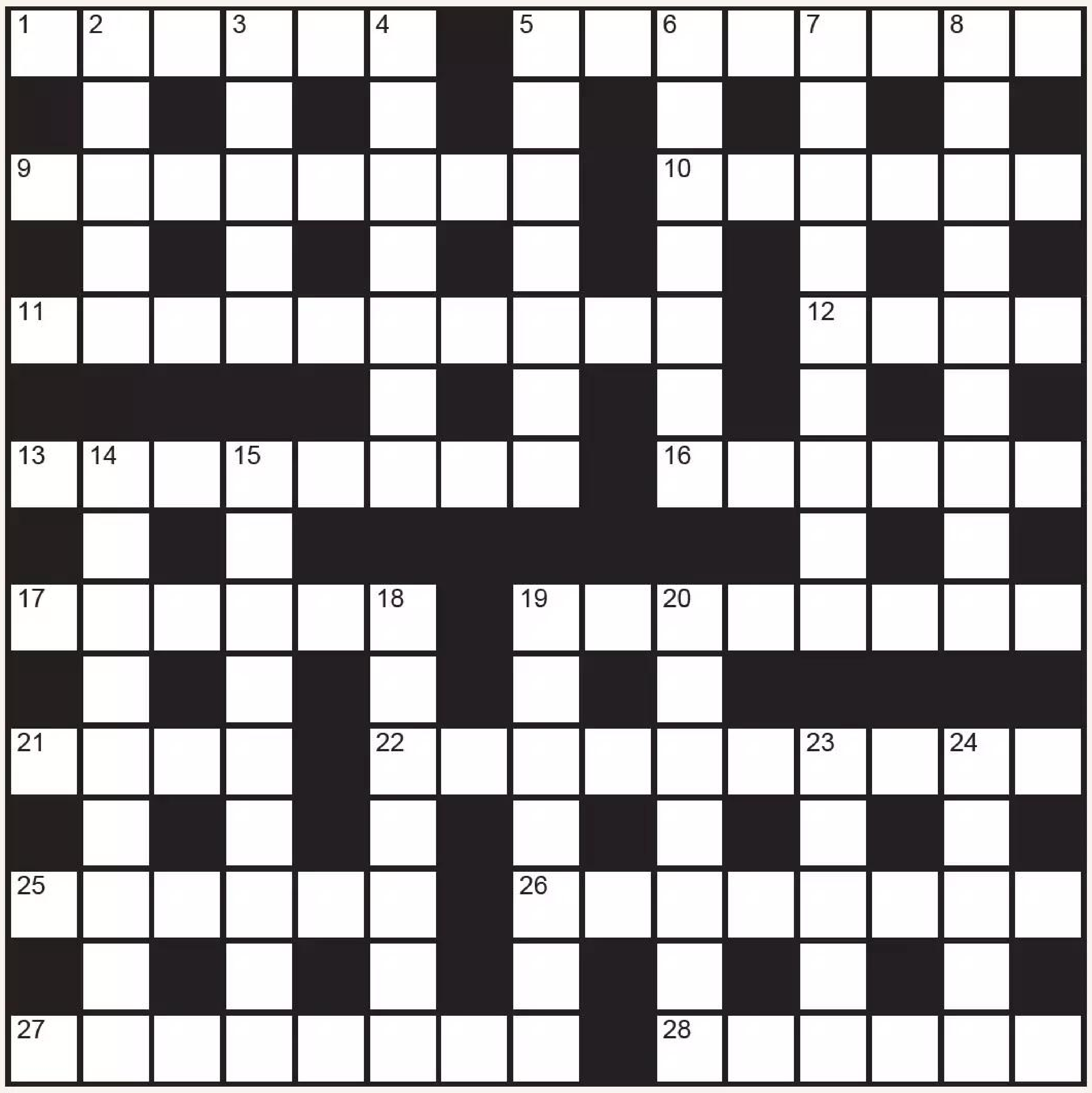
Quick crossword #184 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Small-scale software product (6)
5 Joint inflammation (8)
9 Duck-billed monotreme (8)
10 Feather type (6)
11 Atmospheric boundary (10)
12 Anatomical fold (in the stomach, say) (4)
13 Plant such as love-lies-bleeding (8)
16 ___ bug, insect in the superfamily Pentatomoidea (6)
17 Toxin (6)
19 Concerning the arteries of the heart (8)
21 Marine crustacean (4)
22 Sarin, say (5,5)
25 Space station launched in 1973 (6)
26 Shared characteristic of molecules, in immunology (8)
27 Railway sleeper (8)
28 Ab or quad, perhaps (6)

DOWN

2 ___ bear, *Ursus maritimus* (5)
3 Illuminated (3,2)
4 Property of a ball undergoing forward rotation (7)
5 Bi (7)
6 Condition caused by vitamin D deficiency (7)
7 Air temperature phenomenon (9)
8 Erratic (9)
14 Sci-fi Bond film of 1979 (9)
15 Areas of industrial decline, especially in the US (4,5)
18 Tiny automaton (7)
19 Compound of C with W, V or Zr, perhaps (7)
20 Re (7)
23 Bill ___, Microsoft co-founder (5)
24 Prickly pear (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #304

set by Corryn Wetzel

1 What is the tallest known tree species?

2 How many lobes does the human brain have?

3 Henri Becquerel discovered radioactivity in what in 1896?

4 What does the acronym RAID stand for in data storage?

5 What discovery earned Frederick Banting and John Macleod the Nobel prize in medicine in 1923?

Answers on page 47

BrainTwister

set by Christopher Dearlove

#75 Letters and numbers

Let each letter have a value, where the vowels A, E, I, O and U have value zero and all other letter values are whole numbers greater than zero. The value of a word is the sum of the values of its letters. A word that represents a number is "self-describing" if its value is that number. For example, ONE is self-describing if ONE = 1, for which we must have N = 1.

If TWO and THREE are also self-describing, which other letters can we find the values of?

If we continue with FOUR, etc., being self-describing and retain all deduced letter values, which is the first number word that cannot be self-describing?

What further letter values can we find, following the same rules, skipping over those number words that aren't self-describing but keeping all earlier letter deductions, up to the word TWENTY?

Solution next week

Future fuel

There may be millions of tonnes of white hydrogen available for power. Since each reaction needs oxygen, could it deplete our air supply?

Mike Follows
Sutton Coldfield, West Midlands, UK

In 1987, a well in the Malian village of Bourakébougou unexpectedly ignited when a worker lit a cigarette nearby. The incident drew the attention of a local entrepreneur, who investigated and discovered that the flames were caused by naturally occurring, or white, hydrogen seeping from underground.

White hydrogen is typically created through geological processes in which water reacts with iron-rich minerals, such as olivine, under conditions of high temperature and pressure. This sets it apart from grey hydrogen, which is derived from fossil fuels, and green hydrogen, which is produced using renewable energy sources.

Estimates differ, but the US Geological Survey suggests that there may be approximately 100,000 megatonnes of accessible white hydrogen worldwide.

TERRANCE KLASSEN/ALAMY

Could this supermoon be reflecting enough sunlight to drive photosynthesis?

This week's new questions

Lunar glow **Does a full moon reflect enough sunlight to drive photosynthesis? Is there a cut-off point below which the process simply stops?** ***Pat Sheil**, Sydney, Australia*

Cathartic cry **I recently lost my dog and good friend, Milou, to old age. I cry a lot for him, and it made me wonder: why does crying help us so much?** ***Mike Egan**, Meath, Ireland*

> "Even if all the white hydrogen reacted instantly with oxygen, only 1 in about 1500 oxygen molecules would be involved"

A back-of-the-envelope calculation suggests that there is about 10^{18} kilograms of oxygen in the atmosphere. Even if all the white hydrogen reacted instantly with oxygen, only 1 in about 1500 oxygen molecules would be involved.

Guy Cox
Sydney, Australia

White, or mineral, hydrogen is that which occurs naturally underground. It was originally derived from water, but the oxygen from the water has been mineralised rather than released into the atmosphere.

The questioner's thinking is presumably that when we burn other fuels – coal, oil or wood – they are created by plant photosynthesis, so an equivalent amount of oxygen to that consumed in combustion was released to the atmosphere when the fuel was formed.

But it isn't so simple. In the case of wood, we can be fairly sure that the oxygen released when the wood was formed is still out there. Not so with fossil fuels and white hydrogen, since much of the oxygen released will subsequently have been mineralised in carbonate rocks such as limestone, chalk and dolomite. The Carboniferous period was when much of Europe's coal deposits took shape, and also when huge deposits of limestone were formed.

So, burning white hydrogen won't deplete atmospheric oxygen any more than burning fossil fuels such as coal, and has the bonus of not producing any carbon dioxide. Of course, "green" hydrogen would be even better.

Sam Edge
Ringwood, Hampshire, UK

The simple answer is no.
First of all, the atmosphere has a total mass of about 5.5 quadrillion tonnes. Even though most of this is nitrogen and water vapour, this still means over a trillion tonnes of oxygen, so a few million tonnes of hydrogen fuel aren't going to make much of a dent.

In any case, the oxygen in the atmosphere is constantly replenished by photosynthetic life forms. These convert CO_2 and water into tissue, energy and oxygen. Burning hydrogen cleanly generates only water as the combustion product. (Burning fossil fuels and wood also generates a lot of water, along with CO_2 and other nasties.) Some of this water and a very small proportion of the CO_2 then becomes the feedstock for further photosynthesis.

A lot of research suggests that white hydrogen (hydrogen in the ground) will become as uneconomical for large-scale energy generation as petrochemical fossil fuels are becoming compared with renewables. So, it is likely that a hydrogen economy will pretty soon be using hydrogen split from water using renewable energy or, if it ever becomes feasible, from nuclear fusion. Hydrogen generated this way releases the same amount of oxygen as is consumed when burning it, so it will therefore be "oxygen-neutral".

Spare change

How much money is gained or lost in computer rounding errors in, say, a year? And what happens to this money?

Mel Earp
Macclesfield, Cheshire, UK

The problem of rounding in financial calculations isn't, in and of itself, a computer problem. It has been with us almost since the invention of money.

Try to divide £1 into seven shares and you end up with a fraction of a penny. When society was cash only, this was difficult indeed. In the distant past, coins were even known to be physically cut into pieces. It could be that this was the origin of the old halfpenny and farthings.

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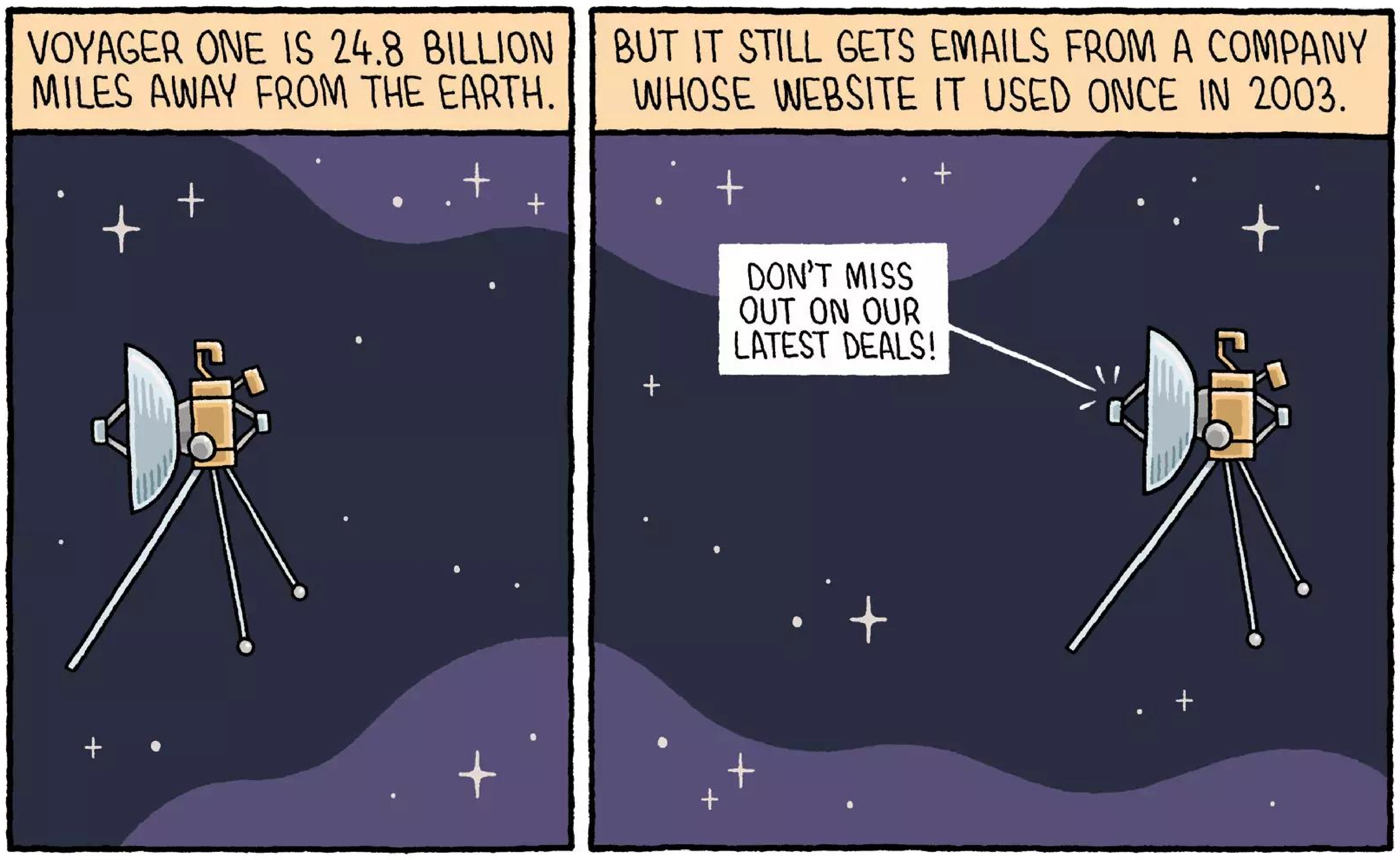
Tom Gauld
for New Scientist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BUT IT STILL GETS EMAILS FROM A COMPANY WHOSE WEBSITE IT USED ONCE IN 2003.
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Rounding itself isn't an error. The error occurs when rounding is accumulated in one direction, up or down. Accounting practices have long guarded against this, even before computers, when everything was pen and paper. This isn't to say that it never happens, but it is unlikely that there is some large pot of rounding money to be had somewhere.

To give an example, suppose I have a debt of £100 to pay in 12 monthly instalments. A simple, rounded calculation says that I should pay £8.33 per month, but this consistently rounds down and produces an error of 4 pence. Of course, what will happen in practice is that four of the payments will be £8.34 (one every three months) or one will be £8.37. The calculation to do this properly is only slightly more complicated than a simple division. And if this wasn't done properly, no money actually disappears. One of the parties will benefit from the 4 pence – in the example I describe, that would be me.

> **"Accounting practices have long since guarded against rounding errors, even before computers"**

Hillary Shaw
Newport, Shropshire, UK

Overall, you might expect rounding errors to cancel out. But in fact, a small amount of "assets" may be destroyed this way. For example, share prices or currency exchange rates will have a long tail distribution of many smaller ones and a few big ones. In other words, there will be a few 100s, more 90s, many more 80s and so forth. And many more .4s, .3s, .2s and .1s would be rounded down than .6s, .7s, and so forth being rounded up.

However, this loss may increase wealth in society. If the distribution of these entitlements becomes less equal as a result of the loss, the wealthy tend to save more, reducing economic activity, whereas poorer people spend all they have, so they keep the economy ticking over. And if the rich gain more wealth, they will probably invest it in real estate, driving up the price of houses for all. Keep rounding share prices down and, overall, the economy gets bigger.

Two of a kind

Binocular vision gives us a 3D perspective, and two ears let us locate the direction of a sound. But why two nostrils? (continued)

Richard Gregson
via email

For both the hunter and the hunted, knowing the direction of the source of a smell is essential. The directional ability of smell location by humans has been known for a long time. Georg von Békésy, who received the Nobel Prize for his work on hearing, also determined that the direction of an odour can be established by humans to about 7 degrees. Remember that when you feel inclined to break wind in an elevator.

Answers

Quick quiz #304
Answers

1 Coast redwood (*Sequoia sempervirens*)
2 Four
3 Uranium salts
4 Redundant array of inexpensive disks
5 Insulin

Cryptic crossword #162 *Answers*

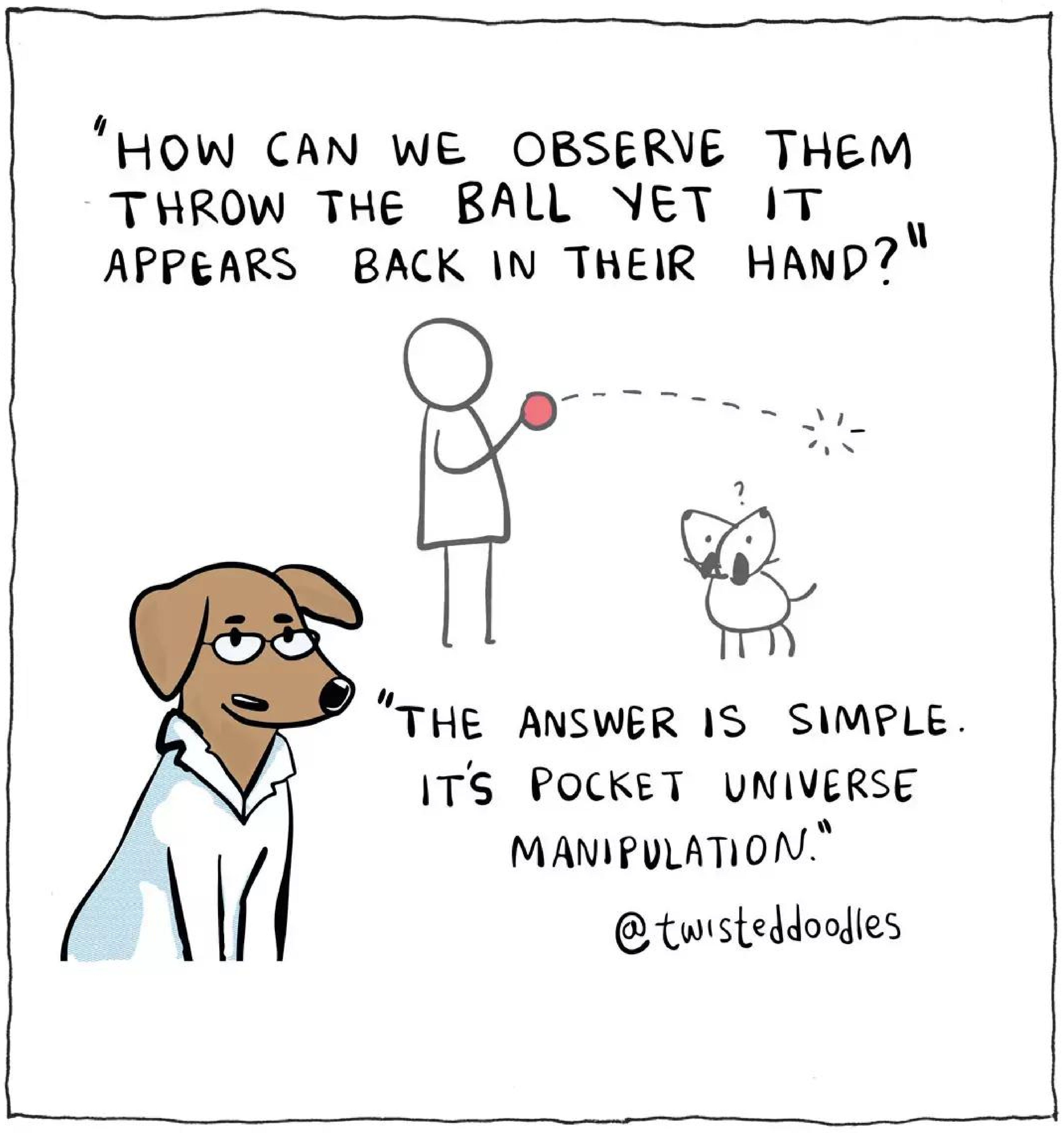
ACROSS 1 Gamelan, **5** Birth, **8** Microwave oven, **9** Ado, **10** Hairballs, **12** Needle, **13** Typist, **15** Mohs scale, **16** Gab, **18** Roll-on roll-off, **20** Locum, **21** Rewired

DOWN 1 Gamma, **2** Macrocephalic, **3** Loopholes, **4** Niacin, **5** Bee, **6** Revolving door, **7** Handset, **11** Boyle's law, **12** Numeral, **14** Fairer, **17** Bifid, **19** Ohm

#74 Triple digits
Solution

The smallest sum possible is 774, which can be made by, for example, 147 + 258 + 369 = 774. The second smallest is 783. One way to do this is 146 + 258 + 379 = 783. Swapping two digits between columns always changes the total by a multiple of 9. For example, to go from 774 to 783, we can swap the 6 in the tens column of 369 with the 7 in the units column of 147 (to get 146 and 379) – so the total rose by 10 and fell by 1, increasing it by 9 overall. Since the smallest total (774) is a multiple of 9 and moving digits changes the total by a multiple of 9, all possible totals are multiples of 9 – so it is impossible to get to 1000. The closest possible total is 999, and can be made as, for instance, 289 + 576 + 134.

Twisteddoodles *for New Scientist*


"HOW CAN WE OBSERVE THEM THROW THE BALL YET IT APPEARS BACK IN THEIR HAND?"
?
"THE ANSWER IS SIMPLE. IT'S POCKET UNIVERSE MANIPULATION."
@twisteddoodles

Got a story for Feedback?
Send it to feedback@newscientist.com
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Consideration of items sent in the post will be delayed

Death of the author?

Now and then, Feedback sees ads for courses promising to teach us how to become an excellent creative writer. It sounds like fun, but why learn to be a good writer when we can just do this stuff instead?

One brand that recently caught Feedback's eye is BBC Maestro. Its course taught by comics legend Alan Moore half-tempted us, but we suspect the professionalised approach might have taken the edges off his thinking. Give us the Moore who believes Northampton is the literal centre of the universe, and who once wrote a 1174-page novel centred on this notion, or give us nothing at all.

Maestro's latest endeavour features a particularly unexpected presenter: crime fiction legend Agatha Christie, who astute readers may realise departed this mortal coil in 1976. The blurb is truly enticing: "In a world-first, the bestselling novelist of all time offers you an unparalleled opportunity to learn the secrets behind her writing, in her own words. Made possible today by Agatha's family, an expert team of academics and cutting-edge audio and visual specialists, as if she were teaching you herself."

Time travel? Cloning? No, this is an AI duplicate of Christie. Actress Vivien Keene was hired to perform the role of the writer, and AI was then used to alter her face and voice.

Something similar – an "avatar powered by gen-AI inspired by Aldous Huxley's science fiction writings" – was on display at UNESCO's World Press Freedom Day event on 7 May. Malka Older, a humanitarian aid worker and science-fiction writer (possibly the greatest portfolio career ever), was there, and was underwhelmed. On Bluesky, she described the avatar as giving "buzzwordy meaningless literal 'maybe both' answers".

It sounds like an enormous amount of hassle to create an AI clone, but we suppose there is a certain security in using bots based on writers who are safely dead and therefore can't be divas in the studio. On the other hand, Feedback is like all writers: always wondering where the next paycheck is coming from. It's bad enough losing out on work to people more talented or charismatic than us – now we're being outcompeted by the dead.

Or as Older put it, with not-even-remotely restrained frustration: "There are! Actual living science fiction writers!... You can invite them to speak!! I promise, many of them are at least as insightful as a white man who has more name recognition but has been dead for 60 years!!!!" Feedback agrees: we want to present our own course in whatever it is we do.

The light of intelligence

It is a truism in science that correlation does not equal causation. Just because one thing seems to vary in line with another doesn't necessarily mean they are actually linked – unless you want to believe that the divorce rate in Maine is driven by per-capita consumption of margarine. It's such a basic point that Feedback wouldn't usually mention it, but every so often we come across a spurious correlation so daft we can't resist.

Reporter James Dinneen draws our gaze to an unreviewed paper with a truly promising title: "Human intelligence forming in the rhythm of solar activity". It reveals a strong correlation between "high-energy solar proton events" and the number of Nobel laureates born in a given year.

The researcher looked specifically at Nobel laureates "in the fields of sciences (including economics) and literature" – and we just want to say that we enjoyed the subtle side-eye inherent in the brackets around "economics".

The number of laureates, the author assures us, has been "adjusted for a six-month prenatal offset". Why not nine months, or five? Could it be the correlation appears only with that specific hack? Regardless, this leads to the hypothesis that "atmospheric radiation patterns... may act as environmental stressors affecting neural circuit formation during prenatal development". Yes, that is certainly one interpretation.

If anyone knows of a more bizarre correlation-based claim, they should send it to the usual address. Meanwhile, Feedback advises anyone who is pregnant to wear tinfoil, just in case.

Cracking stuff

Feedback would like to quit nominative determinism, but we just can't. We were delighted by Andy Green's email alerting us to consultant urologist Nick Burns-Cox, but a hasty archive search revealed we did him in 2019. However, in a genuine novelty, Stephen Alexander highlights the 19 May edition of BBC Radio 4's *The Briefing Room*, the sound engineer for which is one David Crackles.

Sam Edge (who we really hope is a mountaineer) flagged two instances in issue 3540 of this very magazine. Our review of the book *Intertidal*, by a naturalist who began his career bird-watching, somehow failed to flag his "satisfyingly apropos" name: Yuvan Aves. A few pages later, "in your own esteemed column" (see, readers, this is how you get your submissions published; just saying), he noted that "scientific journals were being scanned by one Alexander Magazinov".

Finally, this isn't quite nominative determinism but is clearly adjacent, and anyway, this is our own esteemed column, we can do what we want. Amy Marschall writes on Bluesky: "Omg I just saw a billboard that said 'Erectile dysfunction is a growing problem'". The question being: was this on purpose, or did someone genuinely not realise? ▮

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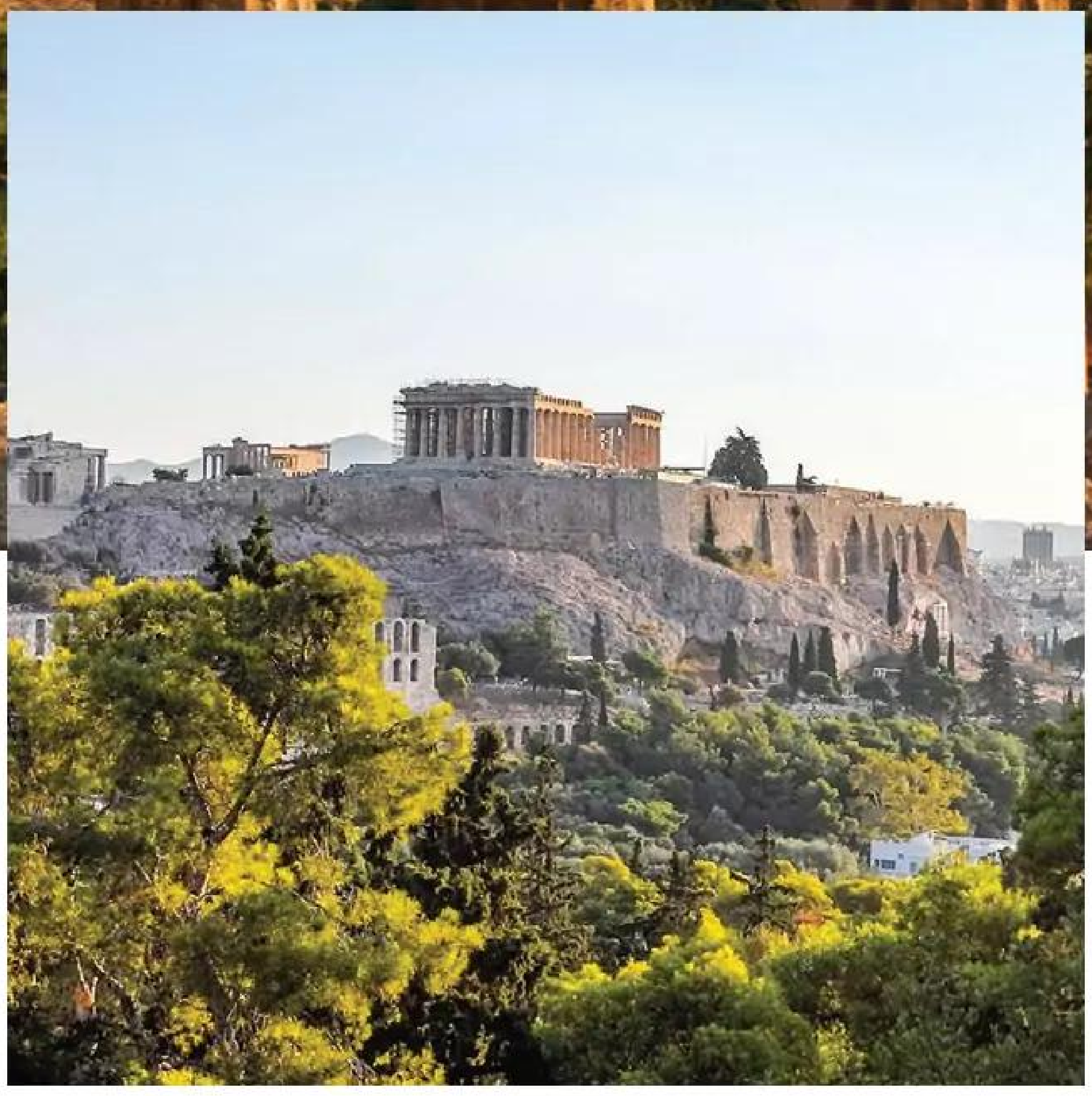

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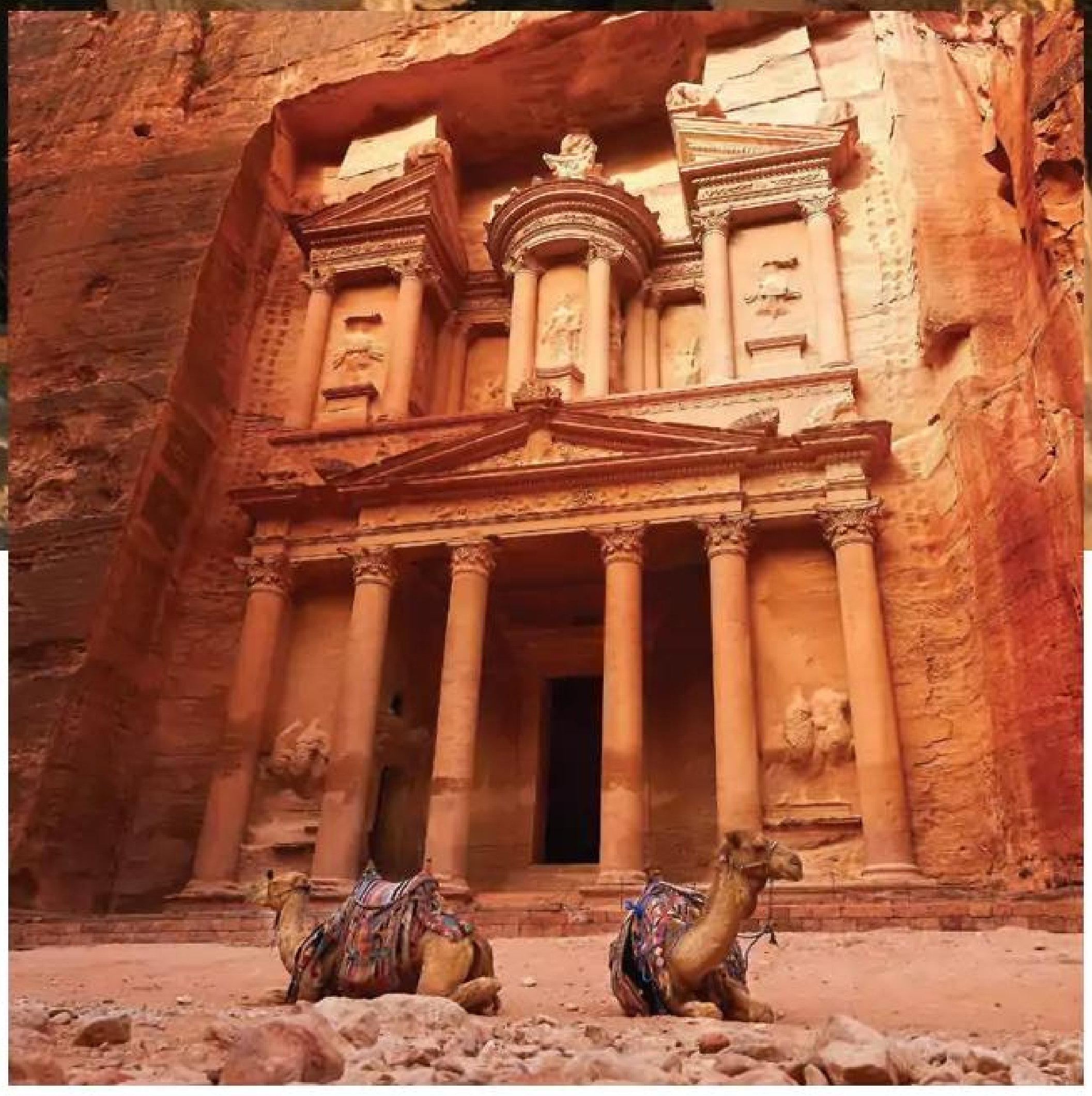

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